Black Bayou Urban Detention Basin
Final Interim Report

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DEQ Contract No. 514399

Submitted to:

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ABSTRACT

The City of West Monroe in Louisiana received a grant through the United States Environmental Protection Agency, Section 319 National Monitoring Program. The primary purpose of this study is to examine the performance of an urban wetland in pollutant removal from stormwater runoff. The wetland is located along Interstate 20 inside the city limits. The sub-watershed of the Black Bayou drainage area is approximately 900 acres. The wetland is located on the outlet of the sub-watershed. The sub-watershed was divided up into four different land uses: construction, residential, wetland, and commercial. The project began February 1, 1998 and continued to December 31, 1999. Rainfall and flow data were monitored for this time period. Sample were collected for 30 rain events, 7 were discarded due to silt build-up on the flowmeter or sampler problems. Discrete and composite samples were analyzed for TSS, COD, TP, NO_3, NH_3, TKN, BOD, oil and grease, fecal coliforms, 11 heavy metals, and TOC.

Clearing and construction for a commercial park caused large amounts of silt to runoff during 1998. This caused silt build-up on the flowmeter at the inlet to the wetland causing inaccurate flow measurements. Basin efficiency for 1998 had more pollutants going out of the wetland than coming in. Basin efficiency increased to 51% for TSS in 1999, due to construction completion causing decrease of silt in the runoff, also the inlet to the basin was dredged at this time, which allowed better flow of water. Monitoring of four different land uses did not statistically result in any significant difference for pollutants discharged from each land use.

INTRODUCTION

1.1 Background

In 1993, Louisiana's Nonpoint Source Management Program conducted a series of workshops on urban nonpoint pollution. These workshops discussed the types of nonpoint source pollution problems in certain areas of the state, and provided information on what steps should be taken to alleviate these problems through implementing best management practices and educational programs. As a result of these workshops, the City of West Monroe submitted a project for funding through the United States Environmental Protection Agency (USEPA), Section 319 National Monitoring Program. The objectives of Section 319 are to provide accurate documentation for controlling nonpoint sources, to improve the technical understanding of nonpoint source pollution, and to show the effectiveness of nonpoint source control technology and approaches. These objectives are to be achieved through intensive monitoring and evaluation of a subset of watershed projects funded under Section 319 (EPA, 1997). Section 319 provides the framework for funding State and local efforts to address pollutant sources not addressed by the National Pollutant Discharge Elimination System (NPDES) program.

Consideration of nonpoint pollution control as well as flood control needs to be addressed when implementing a stormwater pollution prevention program. Louisiana receives a large amount of rainfall, so discussion of water quality must include flood control, drainage, and pollution prevention.

The Black Bayou Watershed encompasses 6430 acres, includes the City of West Monroe and drains into the Cheniere Brake Lake and the Ouachita River. The 1994

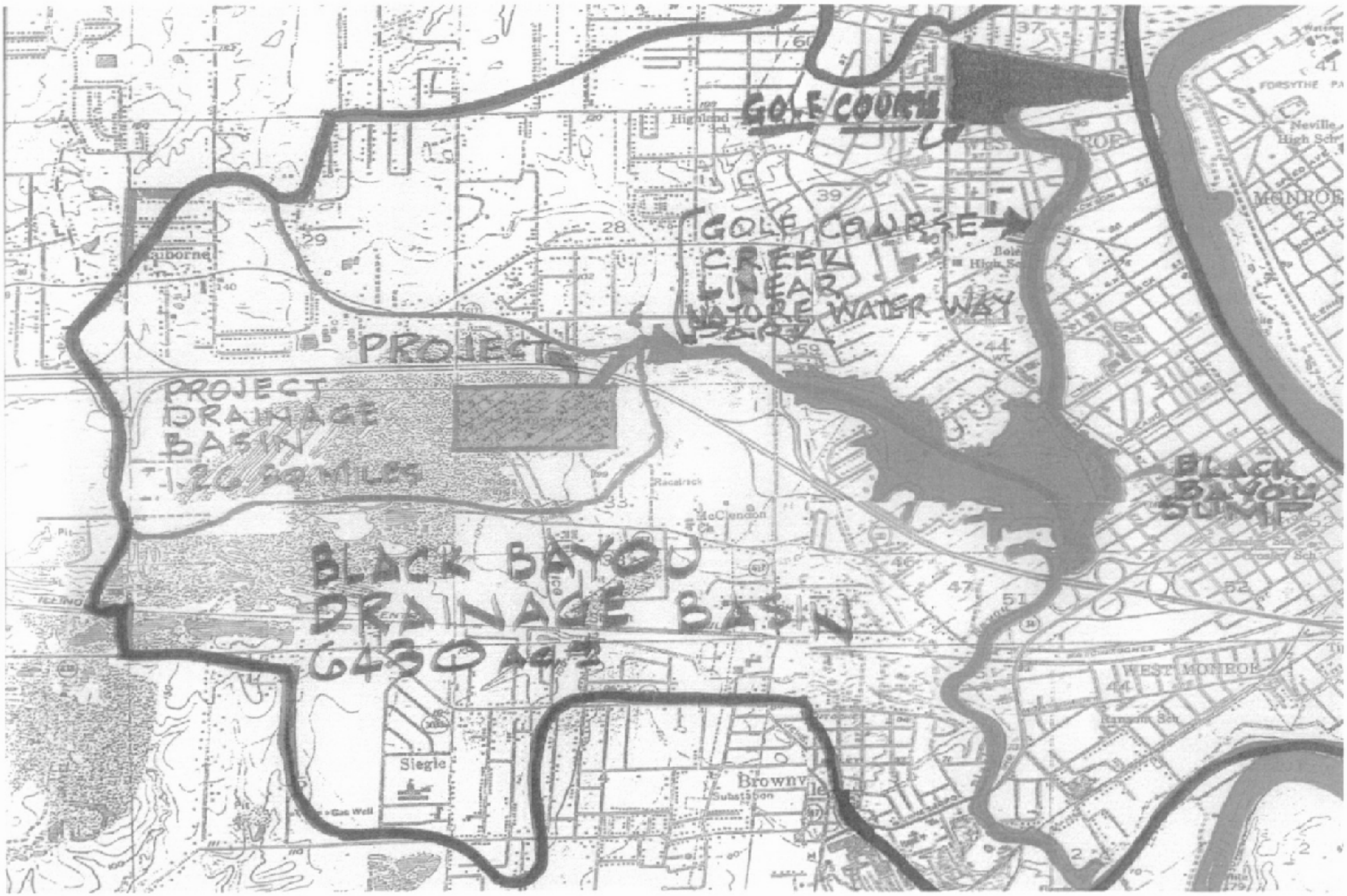


Figure 3: Map of Black Bayou Sub-Watershed

Two inlets into the basin were identified, one from the construction site, called Site 4 (Construction) and the other from a residential area north of Interstate 20 identified as Site 3 (Residential). The Site 4 (Construction) watershed drainage area is approximately 709 acres of which 270 acres drain from north of Interstate 20 east of Well Road and west of Downing Pines Road. The area north of the Interstate is primarily residential with some commercial use. Figures 4 and 5 are different views of Site 4 (Construction) north of the Interstate.

Figure 4: View from Well Road Site 4 (Construction) North of Interstate 20

Figure 5: View of Site 4 (Construction) North of Interstate 20 from Downing Pines Road

The other 438 acres were once an old abandoned gravel pit that had naturally grown into a forested area. This acreage lies south of Interstate 20, and east of Well Road and west of Downing Pines Road. The same month that this project began, the forested site was logged, ponds were drained, and leveling of the land began for construction of a commercial park. Figures 6 and 7 are views of Site 4 (Construction) south of Interstate 20.

Figure 6: View of Site 4 (Construction) from Downing Pines Road south of Interstate 20

Figure 7: View of Site 4 (Construction) south of Interstate 20

The other inlet to the basin is labeled Site 3 (Residential); this inlet drains an area on the north side of Interstate 20, east of Downing Pines Road. This land use is mostly residential with some drainage from Interstate 20. The watershed area from Site 3 (Residential) is 43 acres in size. Figure 8 is the view of Site 3 (Residential) from Downing Pines Road.

Figure 8: View of Site 3 (Residential) north of Interstate 20

The outlet of the Black Bayou sub-watershed is called Site 2 (Wetland). This contains the stormwater detention basin. Site 2 (Wetland) drainage area is approximately 135 acres, with the detention basin being approximately 50 acres of the 135. Figure 9 is the view of the inlet to the basin.

Figure 9: View of Site 2 (Wetland) inlet to detention basin

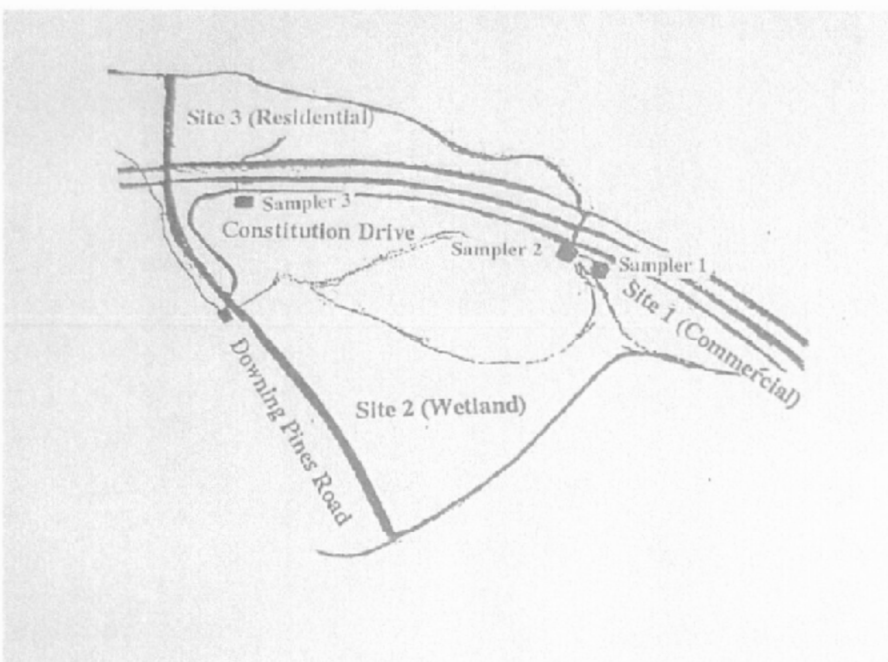


Figure 10: Close-up map of sites 1, 2, and 3.

Site 1 (Commercial) is storm drainage from Constitution Drive and commercial parking lots located west of the outlet on the south side of Interstate 20. It measures approximately 24 acres. Site 1 (Commercial) drains directly into the outfall of Site 2 (Wetland) bypassing the detention basin. Figure 11 is the view of Site 1 (Commercial).

Figure 11: View of Site 1 (Commercial)

2.2 Sampling Methods

2.2.1 Rainfall Measurement

Four American Sigma 900 max all weather, refrigerated samplers were installed at each site. Aluminum buildings were constructed to protect the samplers from weather and vandals. Figure 12 is a photograph of a sampler building with rain gage. Power and

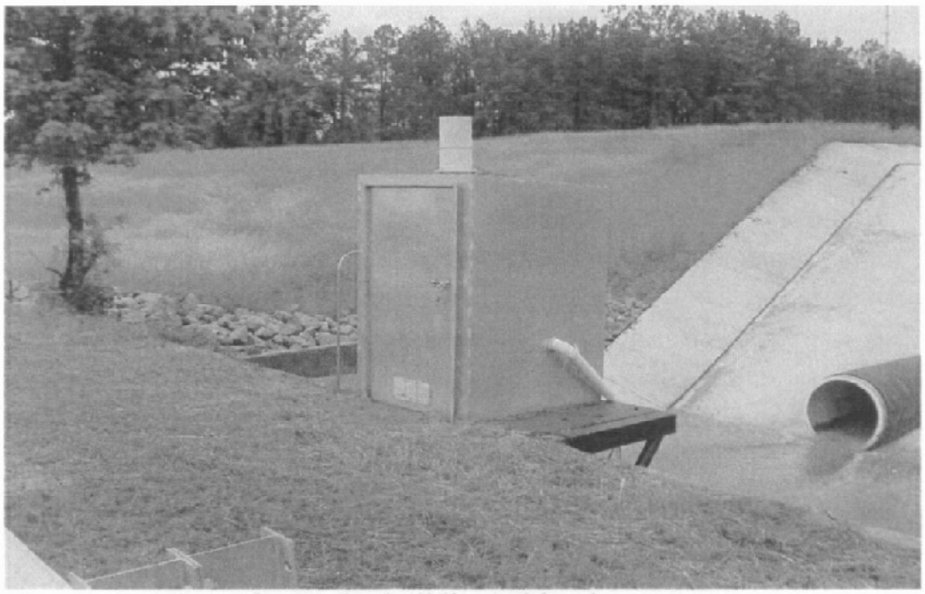


Figure 12: View of sampler building with rain gage

lights were available in each building. A tipping-bucket rain gage was installed on top of the aluminum building at the outlet of the basin, Site 2 (Wetland). Increments of 0.01 inches of rainfall cause the bucket to tip, triggering a signal to the sampler that counted the bucket tips and recorded rainfall. The rain gage was programmed to record the average rainfall that occurred in 5-minute intervals. The rainfall data would then be downloaded to a portable computer after each rain event.

2.2.2 Flow Measurement

Flow measurements were taken by American Sigma flowmeters. These flowmeters use an area velocity submerged sensor, which uses the Doppler method of velocity measurement. The velocity probe sends sound waves through the flow and measures the amount of time it takes for the signal to be reflected back to the probe. Flowrate is then calculated based on the depth of the water and the velocity of the flow in the channel at that point in time. The dimensions and geometry of the channel are programmed into the flowmeter during calibration (American Sigma, 1996). The expression to calculate flowrate based on the geometry of the pipe and velocity of the liquid is:

$$\text{Flowrate} = \text{Wetted Cross Sectional Area} \times \text{Velocity}$$

The channel at Site 4 (Construction) is an 8 feet diameter corrugated pipe. Site 3 (Residential) and Site 1 (Commercial) are both 48-inch circular pipes. Site 2 (Wetland) has two box culverts that have dimensions of 8 x 8 feet. A 920 flowmeter (American Sigma) measures the flow from both channels at Site 2 (Wetland) and logs the flow data every five minutes. Figures 13, 14, and15 show each site outlet.

Figure 13: Site 2 (Wetland) box culverts outlet and Site 1 (Commercial) outlet

Figure 14: Site 3 (Residential) outlet

Figure 15: Site 4 (Construction) outlet

2.2.3 Sample Collection

Each sampler contains 24 bottles, for collection of discrete samples. Samplers are programmed to collect samples every 30 minutes once a setpoint is activated. A peristaltic sampling pump draws a preset sample volume into the sampling bottle. The sampler can be programmed for pre and post purge and rinse cycles to prevent cross contamination. The setpoints at Site 4 (Construction) and Site 2 (Wetland) are based on the level of the water in the channel. Once the level reaches a certain height the sampler is activated and samples are collected immediately, then every 30 minutes after the activation. The setpoints at Site 1 (Commercial) and 3 are based on flow. When the flow reaches the setpoint the sampler comes on, when it drops below the setpoint the sampler shuts off. Sample collection continues every 30 minutes until all the sample bottles are filled or until the rain event has ceased.

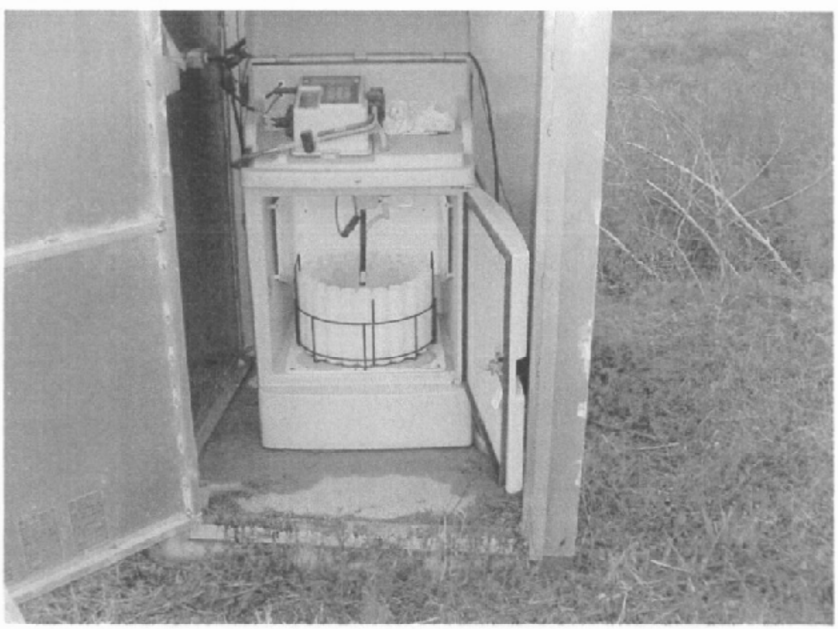


Figure 16: Sampler interior

2.2.4 Data Transfer Unit

A data transfer unit (DTU) is used to transfer data from the sampler/flowmeter. This unit is then downloaded to a portable computer for data analysis. The software used to read the downloaded data is Insight from American Sigma. The data is then stored on a spreadsheet database.

2.2.5 Runoff Grab Samples

During rain events grab samples were collected, on a quarterly basis, using a Nasco swing sampler. The samples were collected, by dipping the sample container below the water surface to fill the container.

2.3 Sample Collection and Analysis

2.3.1 Sample Handling

Rainfall and runoff samples are collected for the monitoring of the Black Bayou Watershed. Discrete samples are collected automatically over each hydrograph at each major inlet and outlet to the basin. Flow and rainfall are concurrently measured and logged by the American Sigma sampler. The samples are stored at 4 °C in polypropylene containers until retrieved. Sample holding times are not exceeded. Sampling equipment logs the time at which the samples were collected and the flow at that specified time. Samples are labeled with the appropriate site location and bottle placement. Samples are transported in iced coolers to the laboratory for sample separation and analysis. Pertinent data is recorded in the logbook located at each site building. Upon arrival to the laboratory samples are logged in.

At the laboratory, samples are separated for composite and discrete analysis. Composite samples are flow weighted and placed into "acid" and "no acid" bottles for analysis. Discrete samples are placed into "acid" and "no acid" bottles for individual analysis. Table 1 lists proper sample storage and preservation requirements from the Quality Assurance Project Plan (QAPP) p. 35. All bottles are labeled appropriately and placed in a refrigerator that maintains a temperature of 4 degrees C.

2.3.2 Sample Analysis

The samples collected from the automatic samplers are analyzed for the following constituents:

Discrete samples:

Chemical Oxygen Demand (COD),

Total Phosphorus (TP), and

Total Suspended Solids (TSS).

Composite samples:

Chemical Oxygen Demand (COD),

Total Phosphorus (TP),

Total Suspended Solids (TSS),

Nitrate-Nitrogen (NO_3),

Ammonia Nitrogen (NH_3),

Biochemical Oxygen Demand (BOD), and

Total Kjeldahl Nitrogen (TKN).

TKN and BOD are analyzed on a quarterly basis because of their low concentrations. If the concentrations increase significantly, then analysis will be run every rain event.

Table 1: Sample Storage and Preservation Requirements

Parameter	Analysis Method (Reference)	Holding Time	Containers (Bottles)	Preservation	Storage Requirements
Coliform, fecal	SM 9222D / 92222B	6 hours	100-ml Sterile glass or Plastic	None	4 degrees C
Ammonia	4500-NH_3 B 4500 - NH_3 E Hach - Method 8038	28 days	P , G	add H_2SO_4 pH<2	4 degrees C
Total Kjeldahl Nitrogen (TKN)	SM 4500 org B or 4500 org C	28 days	500 ml polypropylene	add H_2SO_4 pH<2	4 degrees C
Nitrate-nitrogen (NO_3-N)	SM 4500 NO_3 E	28 days	500 ml polypropylene	add H_2SO_4 pH<2	4 degrees C
Total Phosphorus (TP)	SM 4500-P B & SM 4500-P F	N/A	P , G	add HCL pH<2	(-10) degree C
BOD_5	SM 5210 B	48 hrs	P , G	refrigerate	4 degrees C
COD	HACH method 8000	28 days	P , G	add H_2SO_4 pH<2	4 degrees C
TSS	SM 2540 D	7 days	P , G	refrigerate	4 degrees C
Oil and Grease	SM 5520 C	28 days	G	add HCL pH<2	N.A.
Aluminum (Al)	EPA 200.7	6 months	P, G	add HNO_3 pH<2	4 degrees C
Arsenic (Ar)	EPA 200.7	6 months	500-ml polypropylene	add HNO_3 pH<2	4 degrees C
Cadmium (Cd)	EPA 200.7	6 months	P, G	add HNO_3 pH<2	4 degrees C
Chromium (Cr)	EPA 200.7	6 months	P, G	add HNO_3 pH<2	4 degrees C
Copper (Cu)	EPA 200.7	6 months	P, G	add HNO_3 pH<2	4 degrees C
Iron (Fe)	EPA 200.7	6 months	P, G	add HNO_3 pH<2	4 degrees C
Lead (Pb)	EPA 200.7	6 months	P, G	add HNO_3 pH<2	4 degrees C
Manganese (Mn)	EPA 200.7	6 months	P, G	add HNO_3 pH<2	4 degrees C
Mercury (Hg)	EPA 200.7	6 months	P, G	add HNO_3 pH<2	4 degrees C
Nickel (Ni)	EPA 200.7	6 months	P, G	add HNO_3 pH<2	4 degrees C
Zinc (Zn)	EPA 200.7	6 months	P, G	add HNO_3 pH<2	4 degrees C
Total Organic Carbon	EPA 415.1	28 days	G	add H_2SO_4 pH<2	4 degrees C

P- plastic container
G-glass container
SM-Standard Methods

Grab samples were not collected every rain event. This was especially true when the rainfall occurred in the evening hours. Metals and Total Organic Carbon (TOC) are collected on a quarterly basis. Pesticides are collected annually. Oil and Grease (O&G) and Fecal Coliforms are collected when the rain event occurs.

Table 2 is EPA's list of approved analytical methodology for the aforementioned parameters.

Table 2: Parameters Measured during the West Monroe Black Bayou Study

Test	Method	Source	Test Location
BOD_5	SM 5210 B	Standard Methods[2]	Folk Lab[1]
COD	SM 5220 D	Standard Methods	Folk Lab
TSS	SM 2540 D	Standard Methods	Folk Lab
Nitrate-Nitrogen	SM 4500 NO_3 E	Standard Methods	Folk Lab
Ammonia	SM 4500 NH_3 E	Standard Methods	Folk Lab
Total Phosphorus	SM 4500-PB	Standard Methods	Folk Lab
Fecal Coliform	SM 92222D	Standard Methods	Folk Lab
Oil and Grease	SM 5520 C	Standard Methods	Folk Lab
Total Organic Carbon	EPA 415.1	EPA, Standard Methods	Ana Lab[3]
Aluminum	EPA 200.7	EPA, Standard Methods	Ana Lab
Arsenic	EPA 200.7	EPA, Standard Methods	Ana Lab
Cadmium	EPA 200.7	EPA, Standard Methods	Ana Lab
Chromium	EPA 200.7	EPA, Standard Methods	Ana Lab
Copper	EPA 200.7	EPA, Standard Methods	Ana Lab
Iron	EPA 200.7	EPA, Standard Methods	Ana Lab
Lead	EPA 200.7	EPA, Standard Methods	Ana Lab
Manganese	EPA 200.7	EPA, Standard Methods	Ana Lab
Mercury	EPA 200.7	EPA, Standard Methods	Ana Lab
Nickel	EPA 200.7	EPA, Standard Methods	Ana Lab
Zinc	EPA 200.7	EPA, Standard Methods	Ana Lab

1. Located at Louisiana Tech University
2. 18th Ed. Standard Methods
3. Ana Lab located in Kilgore, TX

Data Analysis

Once recorded, rainfall and flow data are retrieved and samples from the runoff collected. Raw data was analyzed to draw conclusions as to whether the objectives of the research were being met. Appendix A contains the flow and pollutant loads for all monitoring events. The analysis was performed according to the following project objectives:

1. Evaluate the quantity and quality of runoff entering the watershed from upstream areas as a function of land use;
2. Evaluate the effectiveness of stormwater detention basin in reducing nonpoint pollutant flux;
3. Using commercially available software (Mathcad 7.0) pollutant loads entering and leaving the basin can be computed from selected events. This will provide a quantitative measure of basin effectiveness in terms of pollutant removal. This provides a direct measure of the effectiveness of the facility in reducing downstream pollution;
4. By computing and plotting cumulative event volume passing the measuring section vs. the cumulative pollutant load during a runoff event a quantitative measure of the degree of pollutant flushing can be obtained (i.e. 80% of a pollutant is carried into the basin in 20% of the entering flow or vice versa). This effect can be examined as a function of the type and form of the pollutant a well as rainfall characteristics. The same can be done regarding the basin outlet. This provides another quantitative measure of basin effectiveness;
5. Conduct statistical analysis on the data.

3.1 Evaluation of the quantity and quality of the runoff from each catchment

Each sample collected from the four different land uses was analyzed using standard procedures to determine the concentration of the selected pollutants. The data from the analysis were entered into Excel® (Excel, 1995). The file was then used in Mathcad to integrate the pollutant flux over the hydrograph. Pollutant loads for each site obtained from Mathcad were entered into Excel and graphed to compare pollutant loadings. This comparison illustrated the four different types of land use and the amount of pollutants that are discharged from each site per rain event. The rain events from February 11, 1998 to December 6, 1999 are illustrated in Figures 17 and 18, the bar graphs are pounds per inch rain per acre for COD and TSS. These pollutant loads are computed using either composite samples or if composite and discrete samples were analyzed for the rain event then the average of the two were used. Not all recorded events will be used in the data analysis because of problems encountered with silt build up on the probe at Site 4 (Construction) causing inaccurate flow measurements. However, all the recorded data are presented in the Appendix B along with the graphs of each pollutant comparison. The following are the calculations for mass loading per inch rain per acre for each land use:

$$\textit{Pollutant Load/inch rain/acre} = \frac{\textit{concentration of pollutant} \times \textit{flow} \times 8.34}{\textit{Inches rain} \times \textit{land use area}} = \textit{lbs/ac/in}$$

where:

pounds of pollutant computed by integration

rain – amount of rain that fell for the event

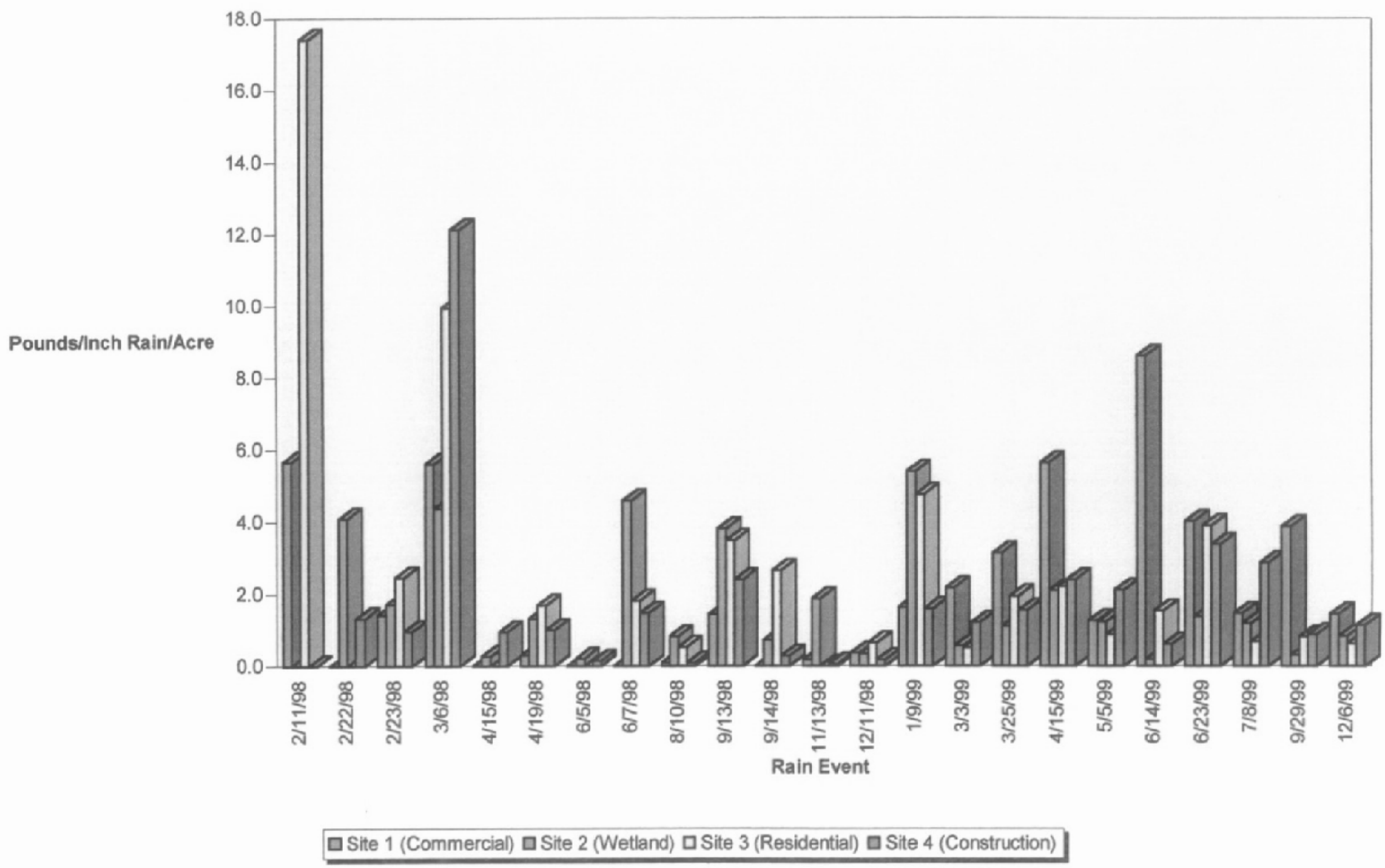


Figure 17: Site Comparison for Each Rain Event COD Pounds/Inch Rain/Acre

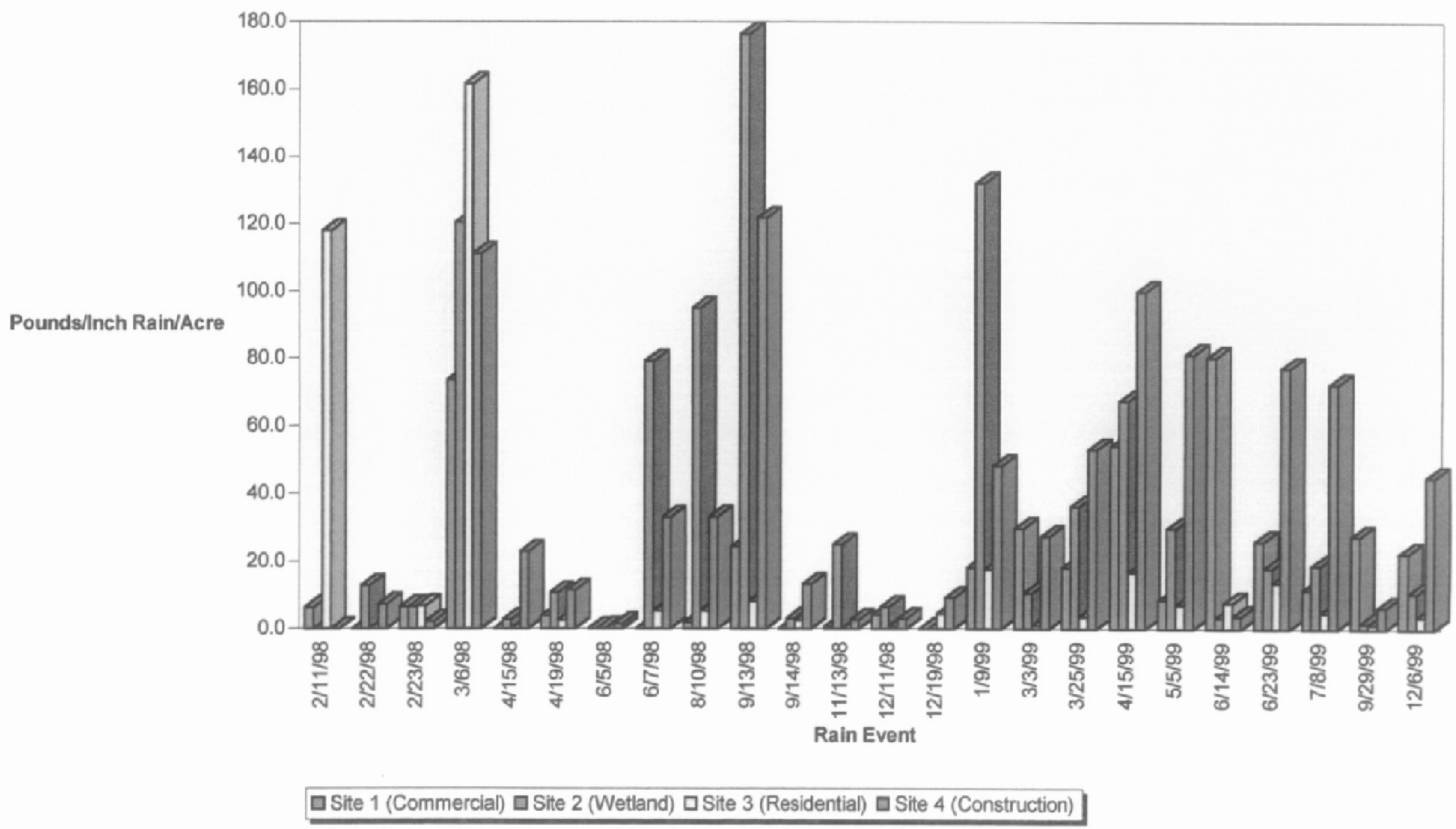


Figure 18: Site Comparison for Each Rain Event TSS Pounds/Inch Rain/Acre

> Acreage of Land Use – watershed acreage for each land use. Site 1-24 acres, Site 2 – 887 acre, Site 3-43 acres, and Site 4 – 709 acres.

The calculations for mass loads are listed in Appendix C.

A flowmeter probe was installed at each inlet to the basin and at the outlet of the basin. Flow was logged every 5 minutes. The runoff volume entering the basin and exiting the basin could then be determined by integrating the hydrograph. A smooth hydrograph was generated using the cubic spline feature of Mathcad. See Appendix C for mathematical calculations. This produced a smooth curve through discrete data points. A sample of the hydrograph for the rain event January 9, 1999 is shown in Figure 19. Examples of various hydrographs are in Appendix D.

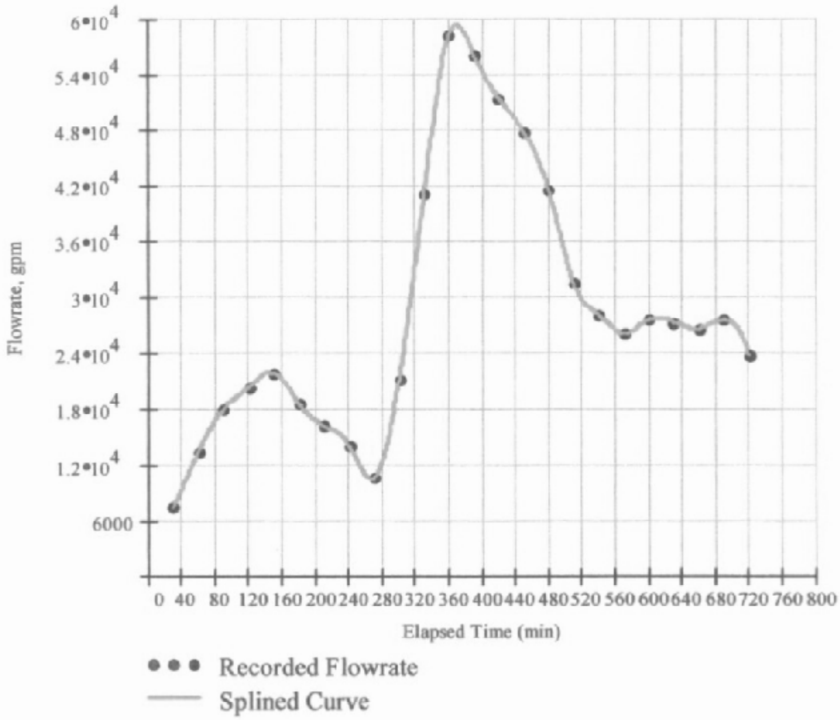


Figure 19: Hydrograph for Site 2 Rain Event 1-9-99

Silt build up in the pipe at Site 4 displaced the water in the channel giving inaccurate flow measurements. The flowmeter calculated the total displacement in the channel as the total amount of flow. The silt level was manually measured each time data was downloaded. The volume of the silt (siltation factor) was calculated and subtracted from each 5-minute interval flow reading beginning March 1999. The volume of the pipe at various heights was calculated using previous data when silt was not a factor, this calculation was then used as the siltation factor. Table 3 is the level of silt and the volume of flow that is subtracted off the five minute recorded flow. If the silt was less than 2.5 inches, the siltation factor was not used.

Table 3: Siltation Factor Calculation

Level of Silt in Channel (inches)	Siltation Factor (sq.ft./gal/min)
2.5	150
3.0	200
3.5	301
4.0	352
4.5	400
5.0	448
5.5	500
6.0	588
6.5	600

Figure 20 illustrates the actual flow measurements from Site 4 (Construction) from the rain event of 1-9-99, downloaded from the sampler, compared to the sample collection during the rainfall event. This comparison illustrates the sample coverage over the hydrograph; further illustrations for the rain events on 3-3-99 and 5-5-99 are in Appendix E.

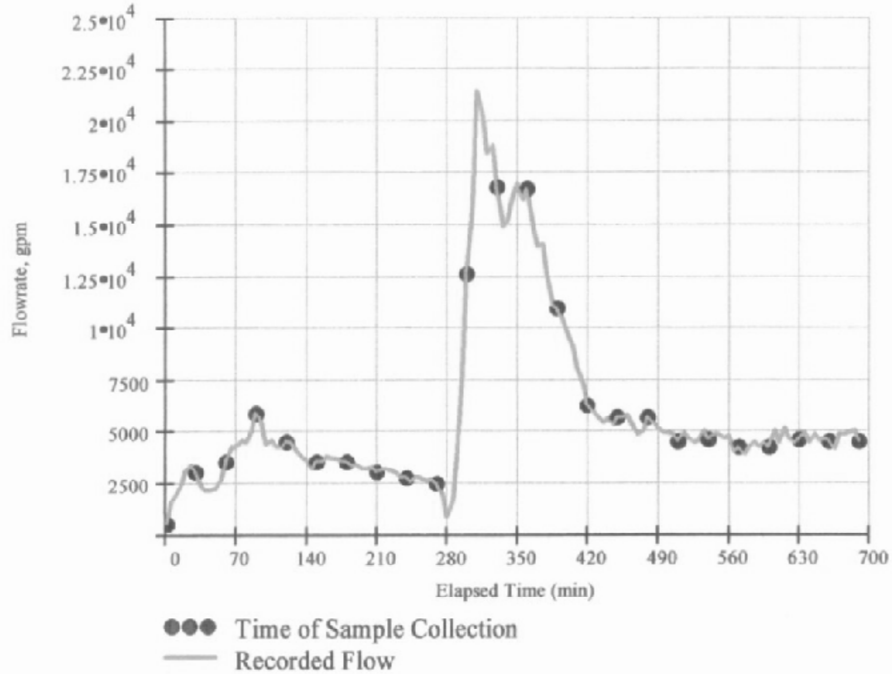


Figure 20: Recorded Flow and Sample Collection from Site 4 Rain Event 1-9-9

Figure 21 on the next page, compares the hydrograph from each site for the rain event 1-9-99. Site 2 (Wetland) had a greater volume of flow than Site 4 (Construction).

3.2 Evaluate the effectiveness of stormwater detention basin in reducing nonpoint pollutant flux:

Pollutant flux is the concentration of the pollutant times the flowrate, and represents the mass of the contaminant transported per unit time (lb/hr) past a point.

Pollutant Flux = Concentration * Flow

where:

- concentration is the pollutant concentration (mg/l) at a point in time, measured by laboratory analysis.

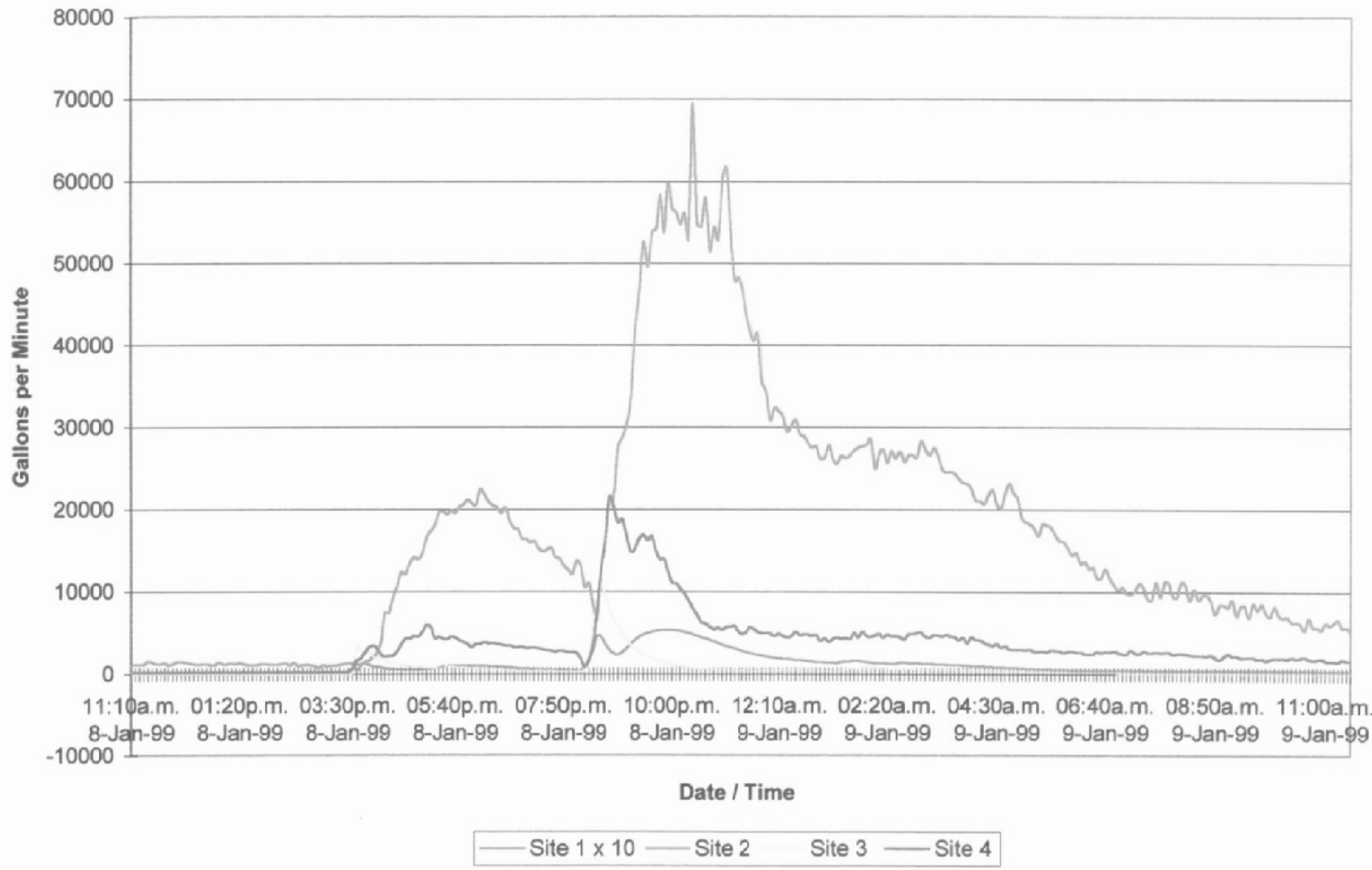


Figure 21: Flow Comparison for January 9, 1999 Rain Event

- flow is the corresponding rate of water flow (gal/min) containing the concentration of the pollutant.

Figure 22 is the comparison of pollutant flux for TSS, TP, and COD for the rainfall event of 1-9-99 for Site 4 (Construction), the scale for each constituent is different, COD values are multiplied by 10 and TP values are multiplied by 1000.

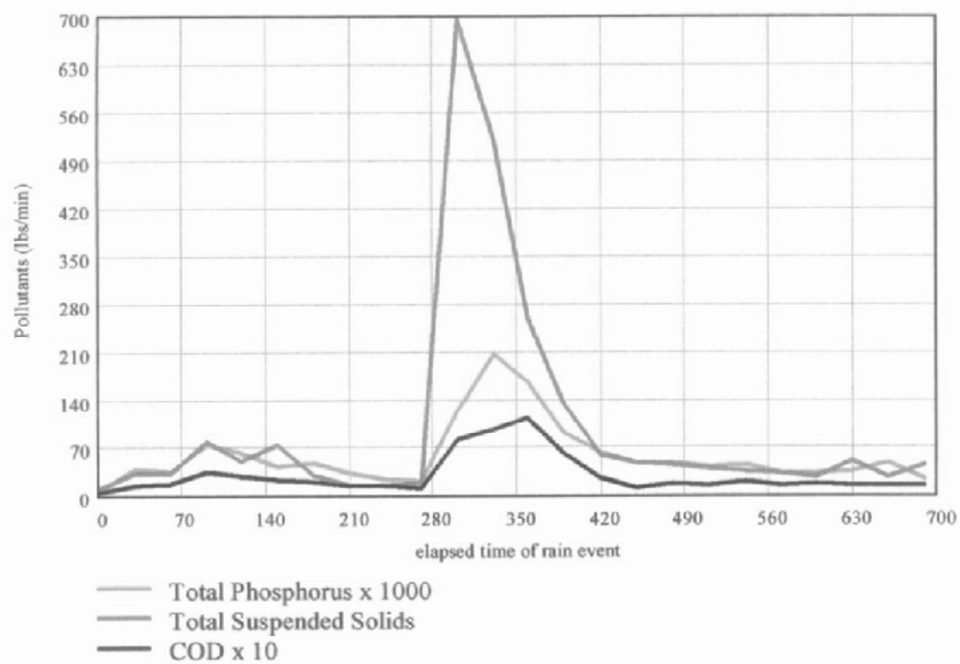


Figure 22: Pollutant Flux Comparison Site 4 1-9-99

This comparison illustrates as the flow increases so does the pollutant flux. More pollutants are being discharged with the increase in flow. There is significantly greater quantity of TSS being discharged than the other two pollutants. Appendix F has the pollutant flux for all four sites from 1-9-99 and 3-3-99.

3.3 Pollutant loads will quantify basin effectiveness in terms of pollutant removal

Pollutant loads or mass loads are the total mass (lb) of the pollutant that was transported in the runoff during the rain event. The area under the mass loading rate versus time curve represents the mass load of the pollutant. The mathematical expression used to calculate the mass load is in Appendix C. The mass loads for each constituent were then placed into Excel® for graphical comparison of basin effectiveness.

Construction of a motel began in October of 1998, upstream from the sampling point at Site 1 (Commercial). Sediment in the runoff became a problem as it accumulated in the outfall pipe and covered the flowmeter. Accurate flow readings were impossible to obtain when this occurred. In January 1999 the construction crew was notified to build siltation fences around the storm drains in an attempt to eliminate sediment in the runoff. In February 1999 the silt was manually cleaned from the pipe. Landscaping occurred at the motel site in March 1999 that dramatically reduced the sediment build-up in the pipe.

Heavy equipment construction at Site 4 (Construction) was complete at the end of 1998. Sediment was coming off the site, but not at the previous rate. Sediment was still piling up on the flowmeter at Site 4 the beginning of 1999. Log weirs and riprap were installed in January to try to impede silt build up on the flowmeter at Site 4. The first storm after the installation of the log weirs washed them downstream, refer to Figure 23 on the next page.

Figure 23: Temporary Weir Placement

The slope of the channel downstream was almost level so water velocity slowed and sediment deposited in the channel. It was decided that dredging the downstream side would help to eliminate the slow velocity thus eliminating sediment from depositing in the channel. The removal of sediment on the downstream side allowed better flow of water so sediment build-up was significantly reduced on the flowmeter at Site 4. This allowed for more accurate flow readings.

Data was separated into yearly comparisons and a comparison from the start of the project to the completion of the project due to the silt build-up on Site 4 flowmeter. Construction at Site 4 was not complete until 1998. Silt build up on the flowmeter caused inaccurate flow measurements, which resulted in inaccurate pounds discharged. Site 4 was not dredged until March 1999, after the dredging silt was no longer a factor. The calculation for basin efficiency is:

Basin Efficiency = (Mass Entering – Mass Leaving)/Mass Entering x 100

or

Basin Efficiency = ((Site 4 + Site 3) – (Site 2- Site 1)) / (Site 4 + Site 3) x 100

Site 1 (Commercial) discharges directly into the outfall of Site 2 (Wetland), the quantity measured at Site 1 are subtracted from Site 2 because they do not flow into the wetland area only into the discharge of the wetland. Thirty rain events were sampled, seven rain events were dropped based on inaccurate flow data or sampler problems. Thirteen rain events from 1998 were used and 10 from 1999. Nine rain events occurred after March 1999, silt build-up on the flowmeters was significantly reduced on these last nine events. Table 4 on the next page, lists all the rain events that were used for analysis in the project.

Heavy Metal Analysis

Grab samples were collected during the rain event for analysis of heavy metals in an attempt to quantify the percent change in metal concentration. Normally, in order to determine the efficiency of a unit process, the mass load in, less the mass load out, plus or minus accumulation is used. However, in this case, concentration of the metals was used instead of mass load. A sample calculation of the procedure used in determining the percent change in metal concentrations is shown below:

% Change in Metals Concentration = ((Site 4 + Site 3) – (Site 2) / (Site 4 + Site 3) x 100

Table 4: Sampled Rain Events

Date	Site 1 COD lbs	Site 2 COD lbs	Site 3 COD lbs	Site 4 COD lbs	Site 1 TSS lbs	Site 2 TSS lbs	Site 3 TSS lbs	Site 4 TSS lbs	Site 1 TP lbs	Site 2 TP lbs	Site 3 TP lbs	Site 4 TP lbs	Site 1 NH3 lbs	Site 2 NH3 lbs	Site 3 NH3 lbs	Site 4 NH3 lbs	Site 1 NO3 lbs	Site 2 NO3 lbs	Site 3 NO3 lbs	Site 4 NO3 lbs
2/11/98	211		1,168		240		7,919													
2/22/98		4,346		1,124		13,686		6,244	0	67.56	0	0		256		71		419		68
2/23/98	40.68	1,884	127	820	166	7,174	356	1,888	0.31	24	1.47	11	1.29	120	6.6	26.5	6.67	192	10	144
3/6/98	356	10,745	1,147	23,041	14,693	291,246	16,634	211,301	4.71	236	12.4	210					17	646	47	654
4/16/98		208		667		2,236		16,265	0	3	0	16		28		181		23		21.6
4/19/98	14	2,378	147	1,445	88	19,339	227	16,533	0.19	40	1.43	34	0.86	307	2.6	198	2.22	248	12.4	120
6/5/98		66		51		70		635	0	0.64	0	0.86		0.99		6.96		6.6		1.9
6/7/98		5,776	111	1,491		99,870	324	33,254	0	134	1.13	5.4		116.5	0.65	13		265	7.6	46
8/10/98	1.84	704	22	56	636	60,974	220	22,613	0.044	62	0.36	3.76	0.27	66.6	0.27	23.8	0.68	116.5	3.79	8.13
8/13/98	73	7216	317	3610	1387	331,361	748	182,220	1.23	136	6.8	56	0.86	126	5.69	44	2.6	246.6	8.78	64
9/14/98		623	93	157		2,231	66	7,682	0	9	1.03	4.3		10.3	1.07	8.4		33.6	20	22
11/13/98	2.8	969		25	64	12,690		1,094	0.01	11	0	0.63	0.08	18.9		0.71				
12/11/98	42	1,458	134	584	616	28,676	179	10,524	0.49	50	1.24	29	0.606	18.9	1.17	8.67	3.18	178	9.5	55.45
1/9/99	74	9,079	385	2,136	965	221,350	1448	64,394	0.82	206	4.72	40.8	0.28	60	0.76	12	4.46	790	1.26	180
3/3/99	33	348	14	560	622	8400	29	12,298	0.45	11	0.12	11.5	0.26	3.8	0.11	8.1	7.79	66	3.8	64.6
3/25/99	67	946	75	984	1626	29,146	143	33,628	0.39	26	0.46	16.7	2.12	26.44	2.61	18.4	10.71	176.7	6.78	142.99
4/15/99	314	4,670	223	3,976	5274	142,614	1,700	165,018	3.01	107	4.8	72	6.3	146	5.67	81	63.27	1979	92.5	1,167
5/5/99	36	1,316	44	1,761	1,130	31,006	358	66,812	0.24	36	0.55	45.5	0.25	12.6	0.31	31	50.6	1955	61.6	2,216
6/14/99	380	682	123	813	7,446	9,110	620	6,009	3.66	12	1.21	11.5	1.61	4.66	0.59	23.4	12.7	236	26	163
6/23/99	156	2,142	272	3,666	3,967	43,946	1,564	143,476	1.64	23	3.8	90	1.04	36	3.6	43	7.23	342	99	649
7/8/99	61	1,584	43	2,646	623	36,444	432	106,350	0.58	57	0.9	83	2.58	21	0.93	41	10.9	491	19.5	765
9/29/99	221	857	85	1,494	4130	12,616	323	26,668	3.76	20	0.94	57	0.24	0.51	0.72	4	11	67	2.78	149
12/6/99	40	900	31	940	853	13,244	214	42,184	0.715	19	0.23	17.6	0.01	3	0.12	2.5	0.4	10.6	0.19	9.7

The grab sample from Site 2 (Wetland) was collected avoiding flow from Site 1 (Commercial); therefore, Site 1 (Commercial) was not subtracted from Site 2 (Wetland) for the calculation of percent change of concentrations. Tables 5-8 show the results of the eleven (11) metals for which grab samples were taken for analysis. These tables show the concentration of the grab sample along with the amount of reduction that occurred in the basin. Most of the samples were in the non-detectable range; for example, Cadmium had all non-detectable values. The % concentration change for these non-detectable values are listed as less than 50% rather than zero because one cannot assume there was no Cadmium present. Percent concentration change for nearly all the metals ranged from the mid-teens to the high ninety percent range. Since the actual sampling time relative to the duration of the rainfall event is not the same for all the samples, the average removal rates are used for the comparison. These average rates excluded zero values and less than 50% values.

Pesticides and PCB's

Pesticides and PCB's samples were collected at the beginning of the project to determine the background level of these pollutants. No pesticides or PCB's were found in that analysis. It was decided to analyze these constituents on an annual basis to see if levels increased over time. There have been no pesticides or PCB's currently found, Table 9 lists the results.

Table 5: Site Comparison and Concentration Changes for Metals

Aluminum (mg/l)

Date	Site 1 (Commercial	Site 2 (Wetland)	Site 3 (Residential)	Site 4 (Construction)	Conc. Change
1/22/98	N/A	5.8	N/A	7.8	25.64
2/15/98	2.8	N/A	1.4	N/A	0
6/5/98	1.4	5.5	0.83	85	93.59
8/12/98	11	30	5.2	160	81.84
12/11/98	30	10.9	7.82	23	64.63
3/30/99	0.598	2.64	3.73	6.66	74.59
6/23/99	2.04	7.79	2.16	38.4	80.79
			Average Concentration Change		**70.18**

Arsenic (mg/l)

Date	Site 1 (Commercial	Site 2 (Wetland)	Site 3 (Residential)	Site 4 (Construction)	Conc. Change
1/22/98	N/A	0.0005	N/A	0.0005	0
2/15/98	0.0005	N/A	0.0005	N/A	0
6/5/98	0.05	0.0005	0.0005	0.0005	<50
8/12/98	0.0005	0.0005	0.0005	0.02	97.56
12/11/98	0.00532	0.00218	0.00224	0.00702	76.46
3/30/99	0.00228	0.00126	0.00223	0.00193	69.71
6/23/99	0.00265	0.0053	0.0046	0.00765	56.73
* 0.0005 less than detection limit			Average Concentration Change		**75.12**

Cadmium (mg/l)*

Date	Site 1 (Commercial	Site 2 (Wetland)	Site 3 (Residential)	Site 4 (Construction)	Conc. Change
1/22/98	N/A	0.004	N/A	0.004	0.00
2/15/98	0.004	N/A	0.004	N/A	0
6/5/98	0.004	0.004	0.004	0.004	<50
8/12/98	0.004	0.004	0.004	0.004	<50
12/11/98	0.004	0.004	0.004	0.004	<50
3/30/99	0.004	0.004	0.004	0.004	<50
6/23/99	0.004	0.004	0.004	0.004	<50
* 0.004 less than detection limit			Average Concentration Change		**<50**

Table 6: Site Comparison and Concentration Changes for Metals

Chromium (mg/l)

Date	Site 1 (Commercial	Site 2 (Wetland)	Site 3 (Residential)	Site 4 (Construction)	Conc. Change
1/22/98	N/A	0.0007	N/A	0.0007	0.00
2/15/98	0.0007	N/A	0.0007	N/A	0.00
6/5/98	0.0007	0.0076	0.0007	0.12	93.70
8/12/98	0.0099	0.033	0.0007	0.28	88.24
12/11/98	0.0336	0.0124	0.00876	0.0684	83.93
3/30/99	0.00747	0.00585	0.00462	0.015	70.48
6/23/99	0.00274	0.0169	0.00488	0.0797	80.02
* 0.0007 less than detection limit			**Average Concentration Change**		**83.28**

Copper (mg/l)

Date	Site 1 (Commercial	Site 2 (Wetland)	Site 3 (Residential)	Site 4 (Construction)	Conc. Change
1/22/98	N/A	0.0006	N/A	0.0006	0.00
2/15/98	0.0006	N/A	0.0006	N/A	0
6/5/98	0.0073	0.0006	0.0006	0.097	99.39
8/12/98	0.009	0.019	0.0006	0.19	90.03
12/11/98	0.0189	0.0098	0.00658	0.0574	84.68
3/30/99	0.00568	0.00615	0.00795	0.015	73.20
6/23/99	0.00701	0.0223	0.0124	0.0665	71.74
*0.006 less than detection limit			**Average Concentration Change**		**83.81**

Iron (mg/l)

Date	Site 1 (Commercial	Site 2 (Wetland)	Site 3 (Residential)	Site 4 (Construction)	Conc. Change
1/22/98	N/A	6.3	N/A	9.3	32.26
2/15/98	2.4	N/A	1.4	N/A	0.00
6/5/98	1.8	14	1.2	160	91.32
8/12/98	14	43	11	370	88.71
12/11/98	31.4	15.5	9.97	78.3	82.44
3/30/99	0.647	6.53	3.89	14.7	64.87
6/23/99	1.78	19.9	4.06	105	81.75
			Average Concentration Change		**73.56**

Table 7: Site Comparison and Concentration Changes for Metals

Lead (mg/l)

Date	Site 1 (Commercial	Site 2 (Wetland)	Site 3 (Residential)	Site 4 (Construction)	Conc. Change
1/22/98	N/A	0.004	N/A	0.004	0.00
2/15/98	0.004	N/A	0.004	N/A	0
6/5/98	0.004	0.004	0.004	0.17	97.70
8/12/98	0.004	0.064	0.004	0.36	82.42
12/11/98	0.0376	0.0099	0.0128	0.058	86.02
3/30/99	0.00746	0.0053	0.00537	0.00935	63.99
6/23/99	0.00512	0.025	0.0128	0.0725	70.69
* 0.004 less than detection limit			**Average Concentration Change**		**80.16**

Manganese (mg/l)

Date	Site 1 (Commercial	Site 2 (Wetland)	Site 3 (Residential)	Site 4 (Construction)	Conc. Change
1/22/98	N/A	0.29	N/A	0.35	17.14
2/15/98	0.091	N/A	0.081	N/A	0
6/5/98	0.091	1.4	0.064	4.9	71.80
8/12/98	0.23	0.87	0.15	8.1	89.45
12/11/98	0.588	0.429	0.23	1.71	77.89
3/30/99	0.233	0.313	0.05	0.338	19.33
6/23/99	0.0645	0.73	0.226	1.28	51.53
			Average Concentration Change		**54.52**

Mercury (mg/l)

Date	Site 1 (Commercial	Site 2 (Wetland)	Site 3 (Residential)	Site 4 (Construction)	Conc. Change
1/22/98	N/A	0.0002	N/A	0.0002	0.00
2/15/98	0.0002	N/A	0.0002	N/A	0
6/5/98	0.0002	0.0002	0.0002	0.00075	78.95
8/12/98	0.0002	0.0002	0.0002	0.00048	70.59
12/11/98	0.000327	0.0002	0.0002	0.000174	46.52
3/30/99	0.0002	0.0002	0.0002	0.0002	<50
6/23/99	0.0002	0.0002	0.0002	0.0002	<50
* 0.0002 less than detection limit			**Average Concentration Change**		**65.35**

Table 8: Site Comparison and Concentration Changes for Metals

Nickel (mg/l)

Date	Site 1 (Commercial	Site 2 (Wetland)	Site 3 (Residential)	Site 4 (Construction)	Conc. Change
1/22/98	N/A	0.001	N/A	0.001	<50
2/15/98	0.001	N/A	0.001	N/A	0
6/5/98	0.001	0.001	0.001	0.12	99.17
8/12/98	0.001	0.024	0.001	0.25	90.44
12/11/98	0.0185	0.0129	0.00656	0.0728	83.70
3/30/99	0.00454	0.00599	0.00505	0.0167	72.46
6/23/99	0.00238	0.0221	0.00569	0.0831	75.11
				Average Concentration Change	84.18

* 0.001 less than detection limit

Zinc (mg/l)

Date	Site 1 (Commercial	Site 2 (Wetland)	Site 3 (Residential)	Site 4 (Construction)	Conc. Change
1/22/98	N/A	0.018	N/A	0.021	14.29
2/15/98	0.048	N/A	0.036	N/A	0
6/5/98	0.093	0.037	0.023	0.28	87.79
8/12/98	0.082	0.11	0.035	0.71	85.23
12/11/98	0.091	0.043	0.0394	0.188	81.09
3/30/99	0.0492	0.0213	0.0288	0.0472	71.90
6/23/99	0.0311	0.0643	0.0423	0.228	76.21
				Average Concentration Change	69.42

Table 9: PCB and Pesticide Analysis from each Site

Organochlorine Pesticides and PCB's (µg/l)								
Date	**2/16/98**	**1/22/98**	**2/16/98**	**1/22/98**	**3/30/99**	**3/30/99**	**3/30/99**	**3/30/99**
Parameters	**Site 1**	**Site 2**	**Site 3**	**Site 4**	**Site 1**	**Site 2**	**Site 3**	**Site 4**
Alpha-BHC	<0.003	<0.003	<0.003	<0.003	ND	ND	ND	ND
Beta-BHC	<0.006	<0.006	<0.006	<0.006	ND	ND	ND	ND
Delta-BHC	<0.009	<0.009	<0.009	<0.009	ND	ND	ND	ND
Gamma-BHC (Lindane)	<0.004	<0.004	<0.004	<0.004	ND	ND	ND	ND
Heptachlor	<0.003	<0.003	<0.003	<0.003	ND	ND	ND	ND
Aldrin	<0.004	<0.004	<0.004	<0.004	ND	ND	ND	ND
Heptachlor epoxide	<0.083	<0.083	<0.083	<0.083	ND	ND	ND	ND
Endosulfin I	<0.014	<0.014	<0.014	<0.014	ND	ND	ND	ND
Dieldrin	<0.002	<0.002	<0.002	<0.002	ND	ND	ND	ND
4,4'-DDE	<0.004	<0.004	<0.004	<0.004	ND	ND	ND	ND
Endrin	<0.006	<0.006	<0.006	<0.006	ND	ND	ND	ND
Endosulfan II	<0.004	<0.004	<0.004	<0.004	ND	ND	ND	ND
4,4'-DDD	<0.011	<0.011	<0.011	<0.011	ND	ND	ND	ND
Endrin aldehyde	<0.023	<0.023	<0.023	<0.023	ND	ND	ND	ND
Endosulfan sulfate	<0.066	<0.066	<0.068	<0.066	ND	ND	ND	ND
4,4'-DDT	<0.012	<0.012	<0.012	<0.012	ND	ND	ND	ND
Chlordane	<0.014	<0.014	<0.014	<0.014	ND	ND	ND	ND
Toxaphene	<0.24	<0.24	<0.24	<0.24	ND	ND	ND	ND
Aroclor-1016	<0.07	<0.07	<0.07	<0.07	ND	ND	ND	ND
Aroclor-1221	<0.2	<0.2	<0.2	<0.2	ND	ND	ND	ND
Aroclor-1232	<0.05	<0.05	<0.05	<0.05	ND	ND	ND	ND
Aroclor-1242	<0.06	<0.06	<0.06	<0.06	ND	ND	ND	ND
Aroclor-1248	<0.07	<0.07	<0.07	<0.07	ND	ND	ND	ND
Aroclor-1254	<0.2	<0.2	<0.2	<0.2	ND	ND	ND	ND
Aroclor-1260	<0.06	<0.06	<0.06	<0.06	ND	ND	ND	ND

* ND is non-detectable

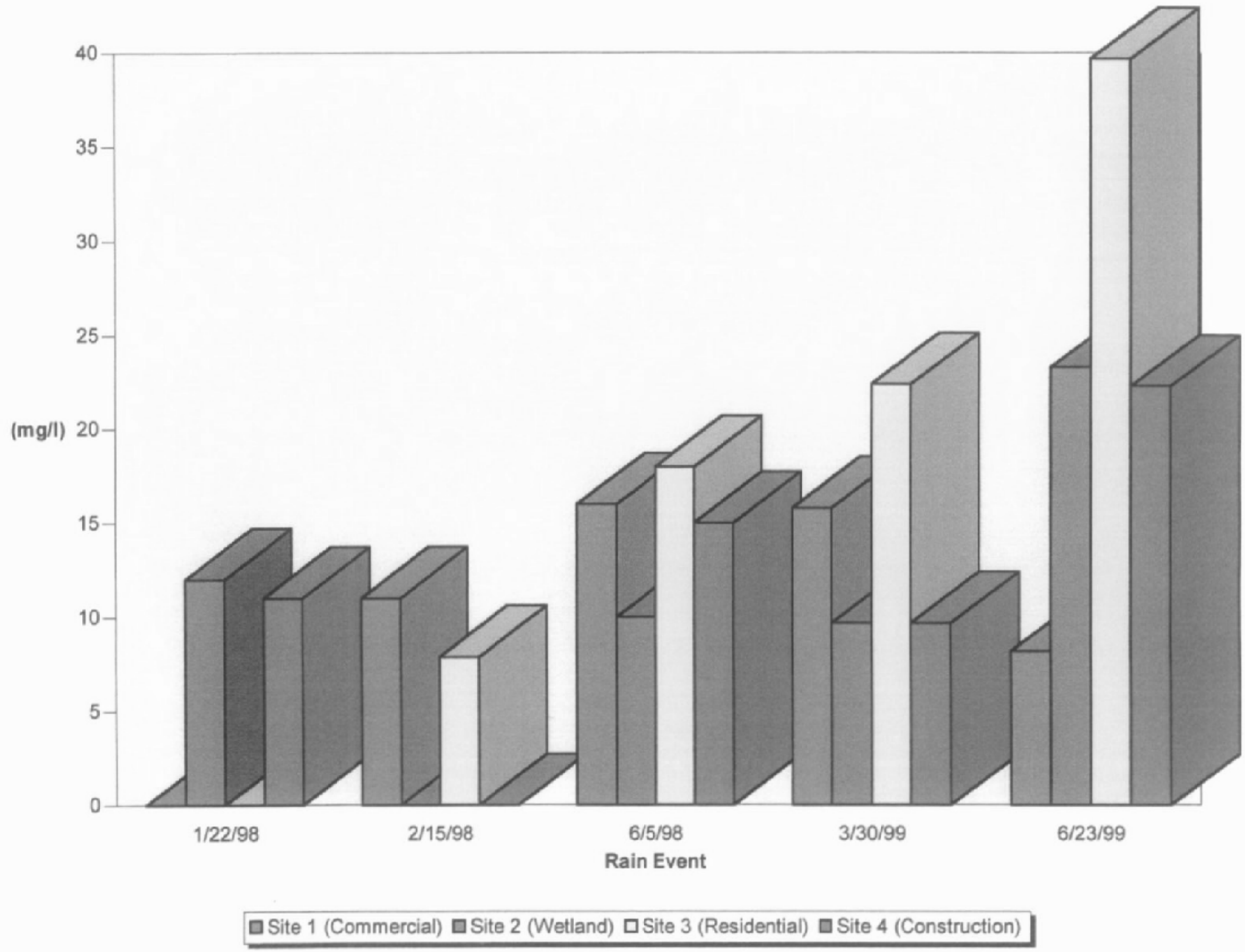


Figure 24: Total Organic Carbon Site Comparison (mg/l)

Total Organic Carbon

Total organic carbon (TOC) was collected as a grab sample. Figure 24 compares the different land uses, these values are mg/l. The graph shows that Site 3 (Residential) and Site 1 (Commercial) had higher mg/l TOC than Sites 2 (Wetland) and Site 4 (Construction). The average change in concentration across the basin was 48%.

Biochemical Oxygen Demand

Biochemical oxygen demand (BOD) were analyzed from composite samples. Table 10 is the pounds discharged and the basin efficiency of BOD for each site. Site 2 (Wetland) discharged more pounds of BOD than all the other sites combined. The concentration of BOD from each site was generally less than 10 mg/l, except on two separate occasions when Site 1 (Commercial) had 25.57 mg/l and Site 2 (Wetland) had 14.27 mg/l readings. Table 11 is the site comparison based on pounds/inch rain/acre for BOD. Site 4 (Construction) and Site 3 (Residential) were almost identical, discharging the least amount per inch rain per acre of landmass, Site 1 (Commercial) was next, and Site 2 (Wetland) had the highest at 2.55 lb/inch rain/acre.

Total Kjeldahl Nitrogen

Total Kjeldahl Nitrogen (TKN) was analyzed from composite samples. Site 3 (Residential) and Site 1 (Commercial) discharged more pounds of TKN per inch of rain per acre than the wetland and construction site, refer to Table 12 and 13.

Table 10: BOD Site Comparison Pounds

Date	Site 1	Site 2	Site 3	Site 4	Basin Efficiency %
2/22/98	0.00	509.20	0.00	145.66	-249.58
2/23/98	0.29	144.50	8.91	91.00	-44.35
6/7/98	0.00	1517.52	0.00	56.65	-2578.64
9/12/98	4.57	19.84	6.21	432.16	96.52
12/11/98	2.07	190.66	9.57	65.23	-152.13
3/25/99	2.93	124.47	5.98	73.25	-53.40
6/14/99	31.37	94.06	11.64	7.08	-234.87
Total lbs	**41.23**	**2600.24**	**42.30**	**871.02**	**-180.19**

Table 11: BOD Site Comparison Pounds/Inch Rain/Acre

Date	Site 1 (Commercial)	Site 2 (Wetland)	Site 3 (Residential)	Site 4 (Construction)
2/22/98	0	0.432	0	0.171
2/23/98	0.01	0.136	0.173	0.107
6/5/98	0	1.205	0	0.056
9/12/98	0.031	0.004	0.028	0.112
12/11/98	0.018	0.045	0.045	0.019
3/25/99	0.138	0.158	0.156	0.116
6/14/99	0.71	0.57	0.146	0.005
Total	**0.907**	**2.550**	**0.548**	**0.587**

Table 12: TKN Site Comparison Pounds Discharged

Date	lbs TKN	lbs TKN	lbs TKN	lbs TKN	Basin Efficiency
	Site 1	Site 2	Site 3	Site 4	%
2/22/98		152.989		48.455	-215.73
2/23/98	0.108	55.705	9.328	34.805	-25.98
3/25/99	4.280	122.025	7.575	86.201	-25.56
6/14/99	8.159	54.707	4.046	37.681	-11.55
Total lbs	**12.547**	**385.426**	**20.949**	**207.143**	**-63.48**

Table 13: TKN Site Comparison Pounds/Inch Rain/Acre

Date	Site 1 (Residential)	Site 2 (Wetland)	Site 3 (Residential)	Site 4 (Construction)
2/22/98		0.144		0.057
2/23/98	0.004	0.052	0.181	0.041
3/25/99	0.201	0.155	0.198	0.137
6/14/99	0.165	0.033	0.051	0.029
Total	**0.390**	**0.384**	**0.430**	**0.263**

Fecal Coliform

Grab samples were used to analyze fecal coliforms. It was difficult to get accurate information from this test, the grab samples from Site 2 and 4 usually contained high amounts of silt. The filters would plug with the silt, if dilutions were made, occasionally no growth would occur. It was difficult to find the correct dilution to use. The time of sample collection, either at the first or last of the rain event, had an impact on the concentration of fecal coliforms. Fourteen rain events were sampled for fecal coliforms. Table 14 lists the results of those events. This test was difficult to quantify; no conclusions can be drawn about this test.

Oil and Grease

Grab samples were collected during the rain event for oil and grease from each site. Pounds of oil and grease were not calculated, a comparison of concentration was used. Most of the values for oil and grease were less than 5 mg/l except on 6-5-98, Site 1 (Commercial) had a value of 17.2 mg/l. Due to this one event, Site 1 (Commercial) discharge more oil and grease than the other sites. Site 2 (Wetland) discharged more than Site 3 (Residential) and 4. The average oil and grease for Site 1 (Commercial) was 3.7 mg/l, Site 2 (Wetland)– 1.8 mg/l, Site 3 (Residential) – 1.3 mg/l, and Site 4 (Construction) – 1.2 mg/l. Refer to Table 15 for the comparisons. These values are relatively low considering the traffic and parking lots around the project area. Appendix J contains graphical displays of pollutants analyzed.

Table 14: Fecal Coliform Site Comparison (colony forming units)

Date	Site 1 (Commercial)	Site 2 (Wetland)	Site 3 (Residential)	Site 4 (Construction)
2/1/98	760	14,560	5,200	13,520
2/15/98	647	13	700	233
2/22/98	1,367	17,160	4,433	8,213
3/6/98	0	7,467	1,313	10,000
3/16/98	800	167	267	0
4/18/98	1,197	1,140	13	11,233
6/5/98	500,000	500,000	500,000	59,000
8/12/98	500,000	500,000	500,000	500,000
9/12/98	203,333	290,000	26,667	176,666
11/12/98	0	0	6,667	3,333
12/11/98	7,450	9,800	14,550	7,400
1/29/99	0	72,520	17,993	306,000
3/30/99	5,900	4,013	3,800	7,550
6/22/99	500,000	500,000	500,000	500,000

Table 15: Oil and Grease Site Comparison (mg/l)

Date	Site 1 (Commercial)	Site 2 (Wetland)	Site 3 (Residential)	Site 4 (Construction)	Basin Efficiency
2/23/98	0	0	0	0	0
4/18/98	2.4	2.5	0	2	-25
6/5/98	17.2	3.4	1.4	1.5	-17.24
8/12/98	1.35	2	4.8	3.65	76.33
9/12/98	1.5	2.9	1.4	0	-107.14
12/11/98	0	0	0	0	0
Average	**3.7**	**1.8**	**1.3**	**1.2**	**26.78**

3.4 Cumulative Load vs. Cumulative Volume

Cumulative load versus cumulative volume illustrates the degree of pollutant flushing. It can be related to the "first flush" effect, which is an increase in pollutants in the first phases of the rainfall event. Knowing this information a detention basin could be designed to handle 50% of the flow and eliminate 70% of the Total Suspended Solid pollutants, Figure 25 is the comparison from Site 1 January 9, 1999.

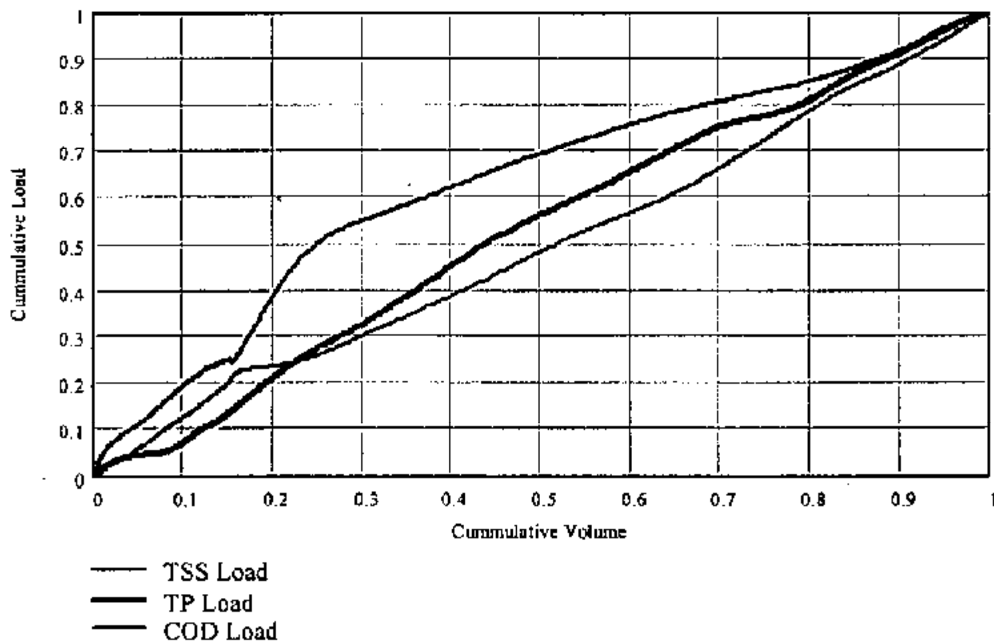


Figure 25: Cumulative Load vs. Volume 1-09-99 Site 1

Appendix G contains the formulas used to calculate cumulative volume and cumulative load. It also contains graphs of cumulative volume versus flow from various rain events.

3.5 Statistical Analysis

Statistical analysis involves assembling, organizing, analyzing, and making inferences from the data (Kottegoda, Rosso, 1997). The use of statistics to try to predict future events is very difficult with stormwater runoff. The following statistical analyses were used to identify any trends in the data:

- Mean, median, standard deviation, and the 10th and 90th percentiles
- Cumulative normal distribution
- Cumulative log normal distribution
- Kruskal-Wallis method
- Mann-Whitney method

Mean, Median, Standard Deviation, and Percentiles

Data tends to cluster around a central value. This value can be used as a representative value of the data set. This feature is called the central tendency, or mean (μ). The following equation is used to calculate the mean:

$$\mu = 1/n \sum_{i=1}^{n} x_i$$

where:

μ = mean of data set
n = number of observations in data set
x_i = data set

Measuring the degree of scatter or dispersion of the data is important in evaluating the variability of the data. The dispersion of the data indicates the spread of the data. The equation for standard deviation is as follows:

$$\sigma = \sqrt{1/n \sum x_i^2 - \mu^2}$$

where:

σ = standard deviation
n = number of observations in data set
x_i = data set
μ = mean of data set

The median is the middle value of the ranked data set. If the mean and median are the same, this suggests the data is symmetrical or normally distributed. When the mean and median are different, the data is said to be skewed.

Because the data is not believed to be normally distributed the 90th percentile and 10 percentile values were computed to give an indication of the range of the data. Table 16 lists the mean, median, standard deviation, and percentile values for each site for COD, Total Suspended Solids, Total Phosphorus, NH_3, and NO_3.

If the data was normally distributed the mean and median of the data would be identical or relatively close. Table 16 illustrates that the data is not normally distributed; for example, Site 2 Total Suspended Solids has a mean of 39 and median of 15. This demonstrates that most of the values are in the lower range with some outlying data points in the upper range. The 90th and 10 percentiles give the range of the data, for Site 2 Total Suspended Solids 10% of the values are less than 2.2 lb/ inch rain/acre and 90% of the values are less than 130 lb/inch rain/acre. Standard deviation is not very useful if the data is not normally distributed.

Cumulative Normal and Log Normal Distribution

Reference distributions or cumulative distributions rank the data values against their corresponding probabilities. No assumptions are made regarding the distribution of the data. Only visual comparison is used to see if the data appears normally distributed. The following equation is used for cumulative distribution:

Table16: Mean, Median, Standard Deviation, and Percentile for Pollutants

COD(lb/in.rain/ac)

Site	Mean	Median	Std. Dev.	90%	10%	Number of Observations
1	2.70	1.60	2.40	5.70	0.18	18
2	1.75	1.20	1.60	4.40	0.22	22
3	3.10	1.80	4.12	9.95	0.53	19
4	1.80	1.20	2.50	2.90	0.11	22

Total Suspended Solids(lb/in.rain/ac.)

Site	Mean	Median	Std. Dev.	90%	10%	Number of Observations
1	23.0	18.0	23.6	73.6	1.9	18
2	39.0	15.0	50.2	130.0	2.2	22
3	19.7	5.3	42.0	118.0	1.1	20
4	38.6	27.6	38.0	110.0	2.3	23

Total Phosphorus (lb/in.rain/ac)

Site	Mean	Median	Std. Dev.	90%	10%	Number of Observations
1	0.0280	0.0180	0.0260	0.0740	0.0019	17
2	0.0380	0.0220	0.0350	0.1000	0.0050	22
3	0.0280	0.0160	0.0280	0.0600	0.0050	18
4	0.0310	0.0250	0.0290	0.0800	0.0030	22

NH_3 (lb/in. rain/ac)

Site	Mean	Median	Std. Dev.	90%	10%	Number of Observations
1	0.0341	0.0186	0.0348	0.1000	0.0050	15
2	0.0508	0.0278	0.0626	0.1500	0.0030	19
3	0.0292	0.0128	0.0328	0.0660	0.0040	18
4	0.0396	0.0292	0.0532	0.0650	0.0020	21

NO_3 (lb/in. rain/ac)

Site	Mean	Median	Std. Dev.	90%	10%	Number of Observations
1	0.380	0.195	0.560	1.400	0.027	16
2	0.283	0.138	0.414	0.927	0.200	21
3	0.348	0.160	0.425	1.235	0.016	18
4	0.242	0.070	0.473	0.599	0.010	21

$$Probability = rank/(n+1)$$

where:

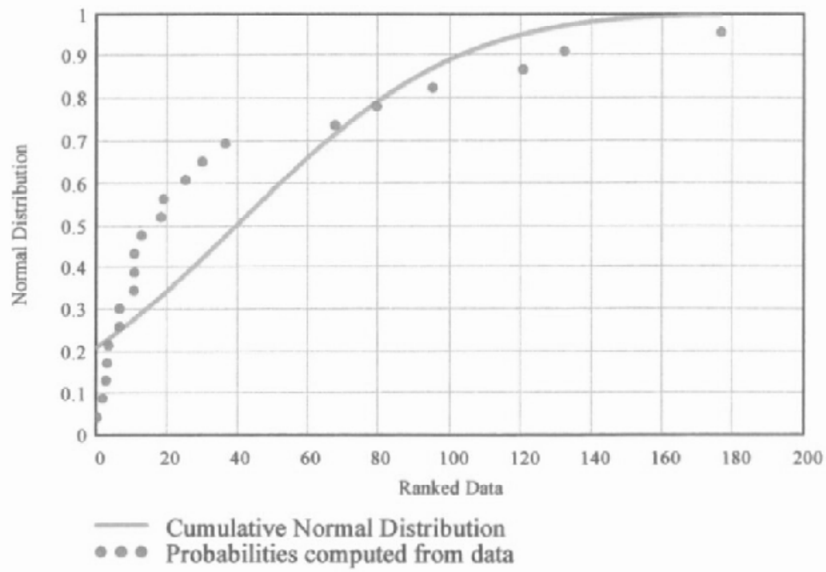
rank = rank of data in descending order
n = the number of observations of the data set

Figure 26 illustrates the cumulative distribution of Site 2 Total Suspended Solids. The data does not follow the distribution curve, so it does not appear to be normally distributed.

Nonpoint pollution data typically does not follow a normal distribution. Log normal distributions are commonly used to characterize environmental data (Bannerman et al., 1993). If the data fits a log normal distribution a cumulative log probability distribution can be performed to determine the probability that a certain value will occur a certain percentage of time. The same procedure is used as the normal distribution but the logarithms of the mean, and standard deviation are used to compute log normal distribution. Figure 26 is Site 2 Total Suspended Solids cumulative log probability distribution. The data points tend to cluster around the distribution curve giving the appearance of a log normal distribution. This curve is in essence a probability plot which can be used to predict future values of the data. Complete reference to calculations for cumulative normal and log normal distributions are located in Appendix H.

Kruskal-Wallis and Mann-Whitney Methods

Usually runoff data does not conform to normal statistics. Normal statistics are also referred to as parametric statistics. This type of statistics is based on the data being normally distributed or having a central tendency. If the data is not normally distributed and the sample size is small, less than 30, then nonparametric methods can be used.



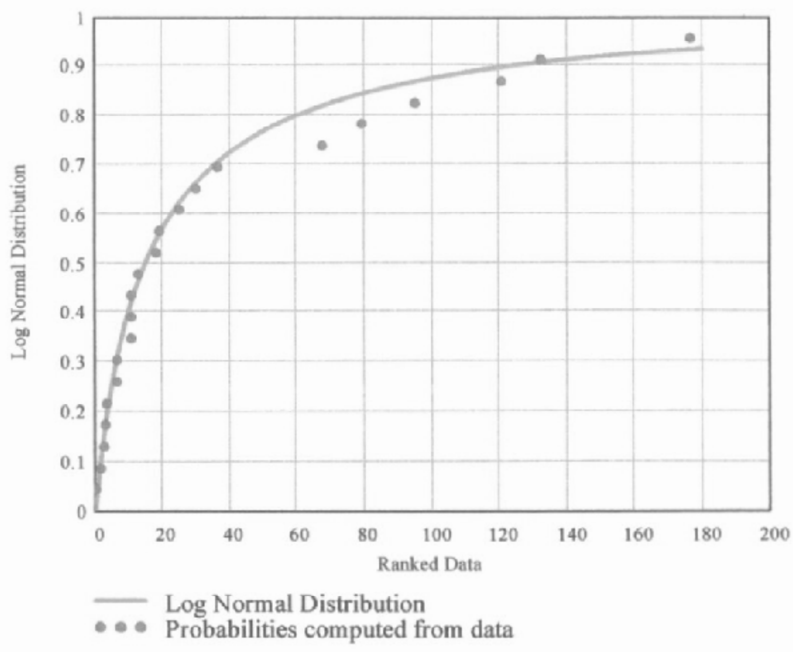


Figure 26: Site 2 TSS Normal and Log Normal Distribution

Nonparametric methods are not concerned with the parameters of populations. They are better at detecting population differences when the assumptions are not satisfied (Mendenhall, 1987). Two methods used to detect population differences in this study were the Kruskal-Wallis method and the Mann-Whitney method.

The Kruskal-Wallis method tests the "hypothesis that all samples are random samples from their individual populations and that there is independence within the samples and between them" (Kottegoda, Rosso, 1997). The hypothesis states that the samples come from the same population. This test avoids the assumption of normality in the data. The number of data sets has to be greater than 2 for this analysis. The Kruskal-Wallis test was used to compare each site for a specific pollutant to see if the four sites come from the same population. Table 17 lists the critical K value for each parameter tested. Appendix I contains the procedure for the test.

Table 17: Kruskal-Wallis Analysis

Parameter	Computed K
TSS	7.598
COD	4.117
NH3	0.539
NO3	3.363
TP	1.119

*critical K value for a 2-sided test at an $\alpha = 0.05$

The Mann-Whitney test is designed for 2 data sets. There are no assumptions about the distribution of either sample or whether the distributions have to be the same. This test analyzes whether one data set tends to have larger observations than the other (EPA, 1997). For example, if the distributions of two samples are similar except for location like Site 2 and Site 4, the Mann-Whitney test can be used to see if the median concentration from one sample is greater than, less than, or not equal to the median concentration from the second sample. Conclusions can be drawn that one site has more pollutants being discharged than the other site. Table 18 is the comparisons of each site using the Mann-Whitney test.

Table 18: Mann-Whitney Analysis

	TSS	TP	COD	NH3	NO3
1 to 2	0.394	0.85	1.34	0.016	0.66
1 to 3	1.95	0.017	0.122	0.615	0.104
1 to 4	1.13	0.439	1.66	0.016	1.53
2 to 3	1.98	0.938	1.203	0.62	0.423
2 to 4	0.488	0:552	0.329	0.075	1.17
3 to 4	2.45	0.299	1.425	0.563	1.479

* critical z value for 2-sided test with $\alpha = 0.05 = 1.96$

Appendix I has the procedure for the statistical analysis using the Mann-Whitney method.

Discussion

History of Project

Results of analyses for Phase I of the Black Bayou Detention Basin Project are discussed in this section. The discussion will deal with the efficiency of the basin, comparison of the effectiveness of the basin in removing pollutants, cumulative loads, land use comparison, and statistical analysis.

Sampling and data collection began February 1, 1998 and ended December 31, 1999. From February 6, 1998 to December 31, 1998 fifty-one rainfall events occurred for a total of 56.32 inches of rainfall. In 1999 ninety rainfall events occurred for a total of 72.73 inches of rainfall. Thirty rain events were analyzed over the length of the project; seven of these rain events were discarded due to silt build up on the flowmeter or sampler error. Appendix J contains the recorded rain fall events from February 19,1998 to December 20, 1999.

The pollutants analyzed were COD, Total Suspended Solids, Total Phosphorus, NO_3, NH_3, eleven heavy metals, BOD, TKN, pesticides and PCB's, total organic carbon (TOC), oil and grease, and fecal coliforms. Discrete analysis and composite analysis were performed on COD, Total Suspended Solids, and Total Phosphorus, the average of the discrete and composite samples were used for the comparisons. Grab samples were collected for heavy metals, pesticides and PCB's, TOC, oil and grease, and fecal coliforms. The data are presented in further detail in separate appendices.

Comparison of basin efficiency was broken down into four categories due to the high amount of silt in the runoff from Site 4 (Construction) in 1998. The categories were: (1.) the beginning of the project in February 1998 to the end of the project

December 1999, (2.) 1998, (3.) 1999, (4.) March to December 1999. Dredging the inlet to the basin at Site 4 (Construction) began in February 1999 and was completed March 1999.

Construction at Site 4 (Construction) began February 1998 and slowed down in December 1998. Silt began to pile up around May 1998, it wasn't until the end of 1998 that the transportation of silt began to decrease. After December 1998 silt was still being transported off the site during heavy rains, but not at the previous rate, due to preventive measures taken by the city.

Construction of a motel upstream from Site 1 (Commercial) started in October 1998 and ended in March 1999. This construction contributed to increased sediment and other pollutant loads. Construction on Constitution Drive began in June 1999. Curb and gutter, water, and sewer lines were installed. Re-surfacing of Constitution Drive occurred in fall of 1999.

Construction of the dam at Site 2 (Wetland) began in August 1999 and ended November 1999. The weather was unusually dry during this period, one sampling event occurred, 9-29-99 during this construction period. A temporary dam was placed to divert the flow into the channel area so construction in front of the box culverts could occur. A 48- inch discharge pipe from the storm gutters off Constitution Drive was placed in front of the box culverts at Site 2. Phase II of the project will monitor this discharge point.

Construction at Site 3 (Residential) occurred in March 1998. The land was cleared and a new channel was dug along Constitution Drive for the discharge.

Basin Efficiency

One purpose of this project is to evaluate the effectiveness of the stormwater detention basin (wetland) in retaining pollutants. Basin efficiency is one way to quantify pollutant removal. Basin efficiency is the mass load in pounds coming into the basin minus the mass load in pounds exiting the basin times 100. Separating the basin efficiency into different categories allows closer analysis of the effectiveness of the basin in removing pollutants. The categories for analyzing the effectiveness are; Overall pounds discharged per site from the beginning of the project February 1998 to the end of the project December 1999, pounds discharged in 1998, pounds discharged in 1999, and pounds discharged in 1999 after dredging the downstream channel at Site 4 (Construction). The overall reduction of pollutants was significantly less than the reduction of pollutants after the dredging. Table 19 illustrates the efficiency of the basin for pollutant removal. This table is the sum of the total pounds discharged from each rain event. Appendix K contains the site comparisons for each individual rain event and graphic comparisons.

The efficiency of the basin from the start to the end of Phase I of the project ranged from (–1%) to (–57%) for the pollutants tested. The negative values resulted from more pounds of pollutants being discharged from the outlet of the basin than were flowing into the basin. Total Suspended Solids had (-14.7%) basin efficiency, Total Phosphorus was (-44.5%), COD (0.75%), NO_3 (-15.61%), and NH_3 (-57.6%). The basin efficiency in 1998 for pounds discharged ranged from (-87 % to 2%) for the above mentioned parameters. Basin efficiency improved in 1999 for removal of pollutants from a (-8% to 23%) The basin efficiency increased further after the dredging at Site 4

Table 19: Basin Efficiency

	Overall Project Efficiency	Efficiency 1998	Efficiency 1999	Efficiency April to Dec 1999
Total Phosphorus (lbs)	-44.50	-87.35	-12.95	23.59
Total Suspended Solids (lbs	-14.70	-61.70	22.97	50.94
COD (lbs)	0.75	2.22	-1.83	33.44
NO_3 (lbs)	-15.61	-76.13	-1.68	8.98
NH_3 (lbs)	-57.61	-82.43	-5.82	7.91
BOD (lbs)	-180.20			
TKN (lbs)	-63.48			
Oil & Grease (mg/l)	26.78			
Total Organic Carbon (mg	48.20			
Aluminum (mg/l)	70.18			
Arsenic (mg/l)	75.12			
Cadmium (mg/l)	<50			
Chromium (mg/l)	83.28			
Copper (mg/l)	83.81			
Iron (mg/l)	73.56			
Lead (mg/l)	80.16			
Manganese (mg/l)	54.52			
Mercury (mg/l)	65.35			
Nickel (mg/l)	84.18			
Zinc (mg/l)	69.42			

(Construction) the parameters ranged from 8% to 51% removal of pollutants. Figure 27 is a graph that illustrates basin efficiency for each category.

Large amounts of sediment were discharged in 1998 due to the runoff of Site 4 (Construction). Site 2 (Wetland) discharged more pounds of Total Suspended Solids until the dredging occurred. Site 4 (Construction) discharged 1.4 million pounds, or 700 tons, of Total Suspended Solids over the project period, half of that amount occurred in 1998. Site 2 (Wetland) discharged 1.76 million pounds, or 880 tons, of Total Suspended Solids over the project period with 1.2 million pounds being discharged in 1998. The discrepancy of pounds discharged could be due to the build up of silt on Site 4 (Construction) flowmeter, the extent of the inaccuracy is not known. Figure 28 is the flow comparison from all the sites from 1-9-99. Site 2 (Wetland) had a much greater magnitude of flow than Site 4 (Construction). The hydrographs follow the same pattern so the flow meter is reading the fluctuating flow at Site 4 (Construction), but the magnitude of the flow was significantly less than Site 2 (Wetland). Figure 29 is the flow comparison of all the sites from the rain event on 3-3-99; this was the first event after the dredging. The flow patterns follow each other and the magnitudes of the flows are similar. The degree of inaccuracy of flow data cannot be determined at this time. Data collected before the dredging was not discarded because based upon sample collection over the hydrographs (see Appendix D) the rain events had good sample coverage.

The basin did not retain any solids during 1998 time period, in fact solids were scoured based on the efficiency data. Decrease in solids entering the basin and the increased accuracy of the flowmeter after the dredging gave a more realistic assessment of pollutants entering the basin, therefore more accurate basin efficiency.

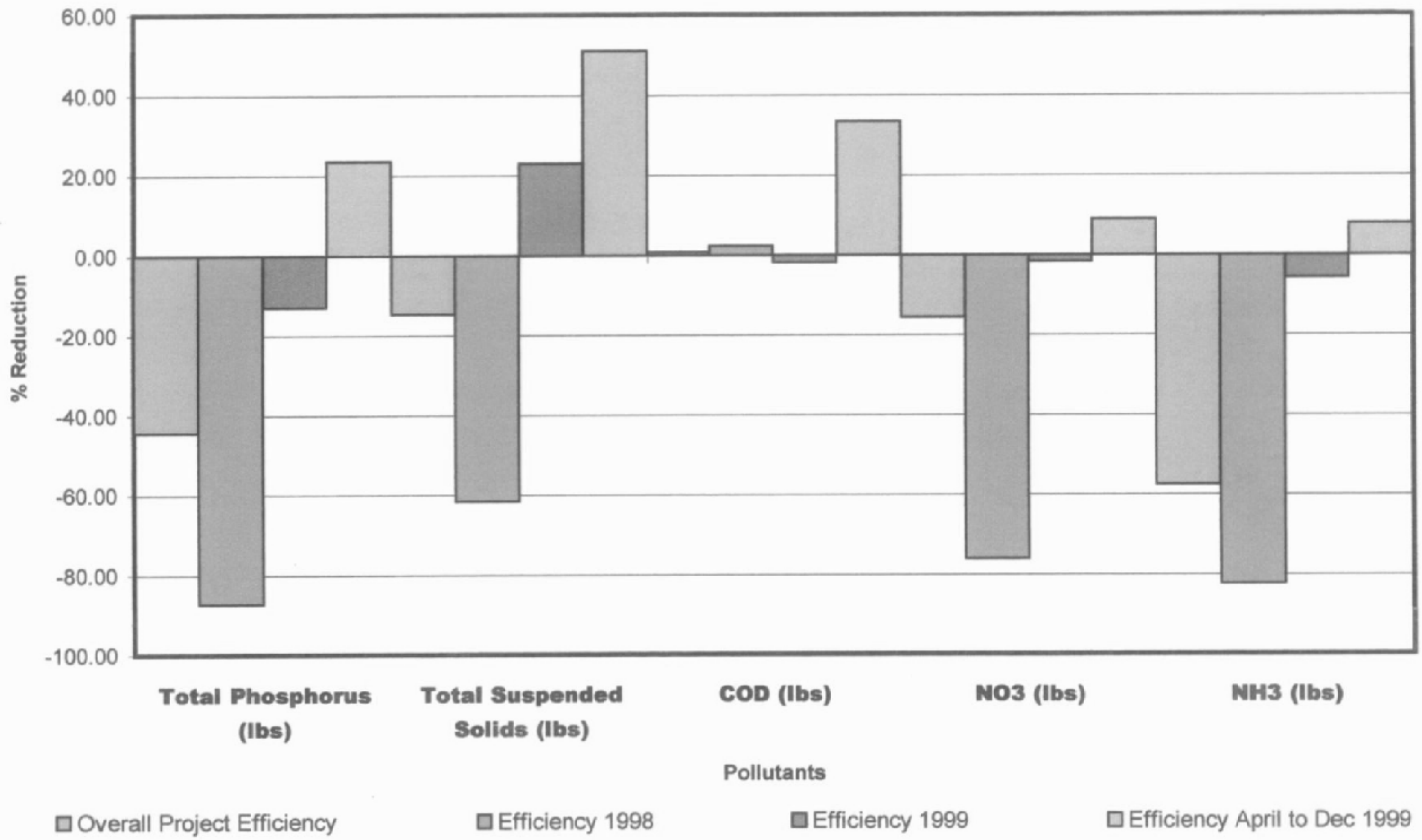


Figure 27: Basin Efficiency for Pounds of Pollutants Discharged

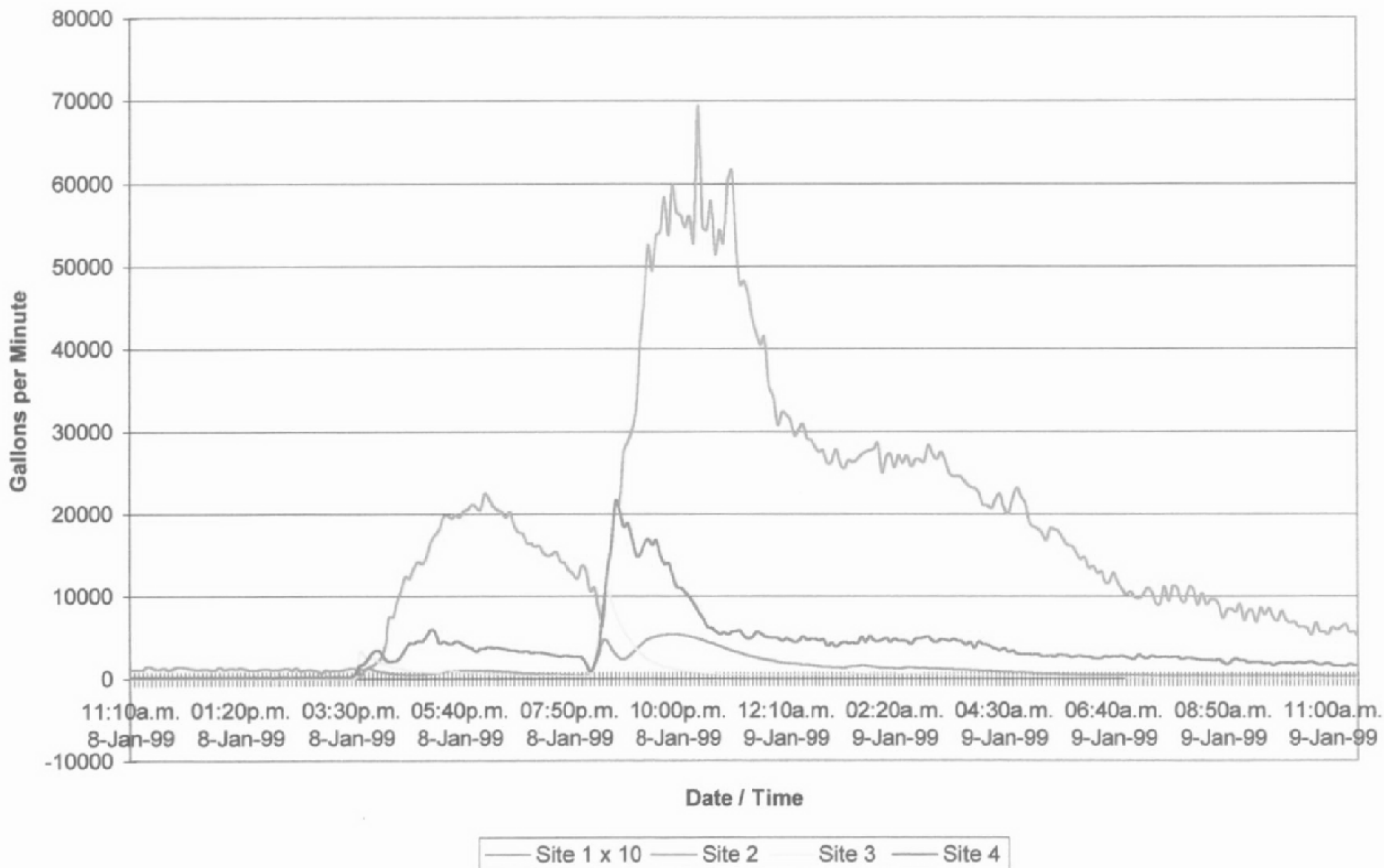


Figure 28: Flow Comparison for January 9, 1999 Rain Event

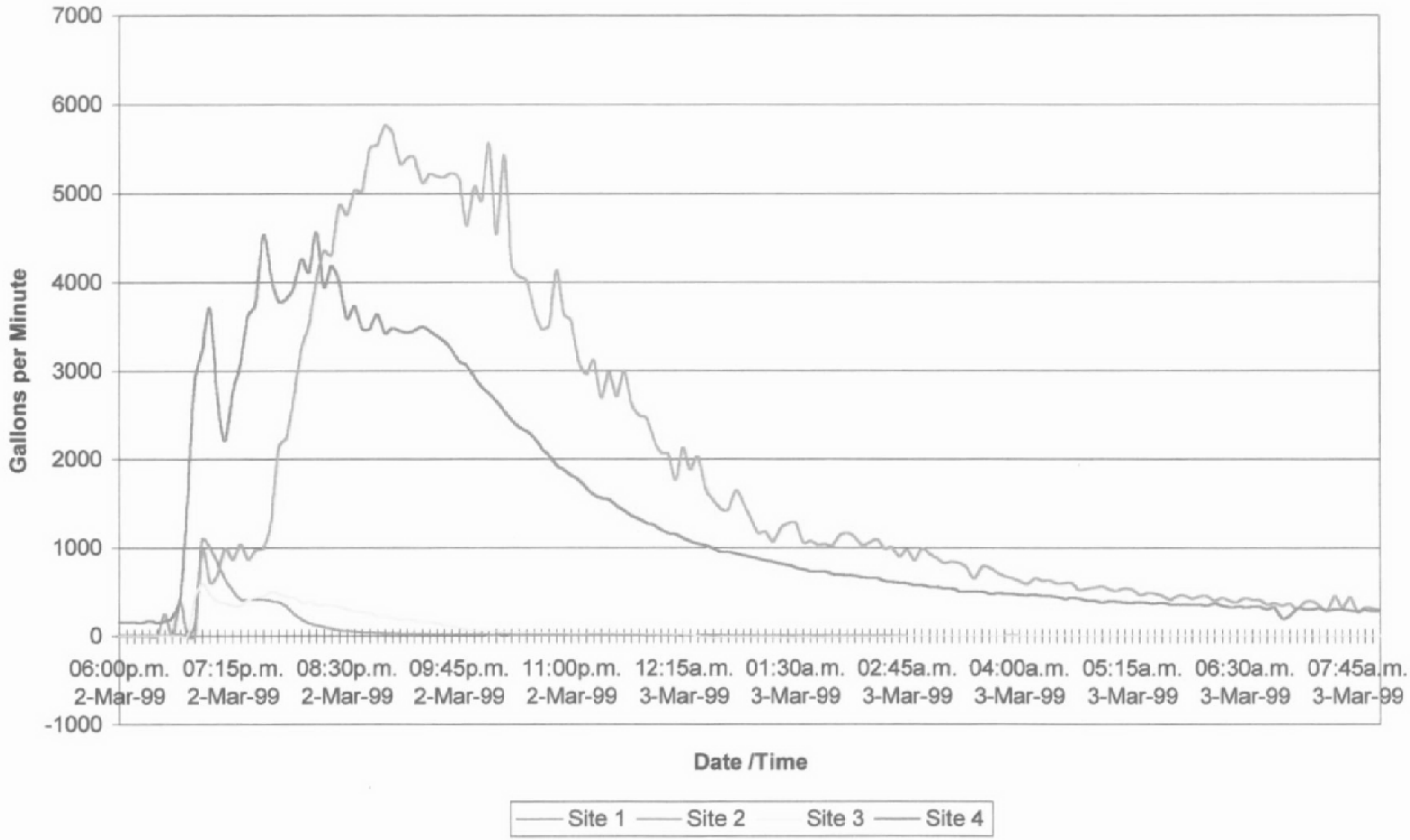


Figure 29: Flow Comparison for March 3, 1999 Rain Event

Construction at Site 1 (Commercial) impacted the pollutants discharged during 1999. The pounds of sediment discharged from Site 1 (Commercial) in 1999 was 68% higher than the amount discharged in 1998. Site 1 (Commercial) more than doubled the amount of pounds of Total Phosphorus discharged from 1998 to 1999. All of the parameters increased on Site 1 (Commercial) from 1998 to 1999.

Site 3 pollutant load decreased from 1998 to 1999 except for NO_3, which increased dramatically. Site 4 (Construction) poundage increased for all the pollutants except COD and NH_3 from 1998 to 1999. This could be due to the accuracy of the flowmeter resulting in higher recorded flows therefore higher pounds discharged. Site 2 (Wetland) pounds of pollutants discharged decreased from 1998 to 1999, except NO_3, which increased. COD and Total Suspended Solids significantly decreased at Site 2 (Wetland) after the dredging of Site 4 (Construction).

The average change in concentration for the eleven (11) metals analyzed ranged from a low of 54.5% for manganese to a high for iron of 87.8%. Most of the concentration changes fell in the 60-70% range.

The overall basin efficiency for BOD was a negative value because there was more BOD being discharged from the basin than entering. There is no explanation as to why Site 2 (Wetland) discharged more pounds of BOD other than more biological activity occurs in the wetland than the other land use sites.

Basin efficiency for TKN had a (-63.48%) for the total pounds removed by the basin. Site 2 (Wetland) discharged more pounds of TKN than the other sites. This accounts for the negative value on basin efficiency, but based on acreage of land use it did not discharge the most TKN.

Cumulative Loads

Pollutants transported in runoff are generally higher in the initial stages of the runoff followed by a gradual decrease in the loads with the continuation of the runoff; this can be referred to "first flush". Pollutant flushing can be illustrated by comparing cumulative volume passing the measuring section versus cumulative pollutant load. Figure 30 is the graph from Site 1 (Commercial) for March 6, 1998 rain event, which illustrates that 50% of the flow has approximately 85% of the pollutants for Total Suspended Solids.

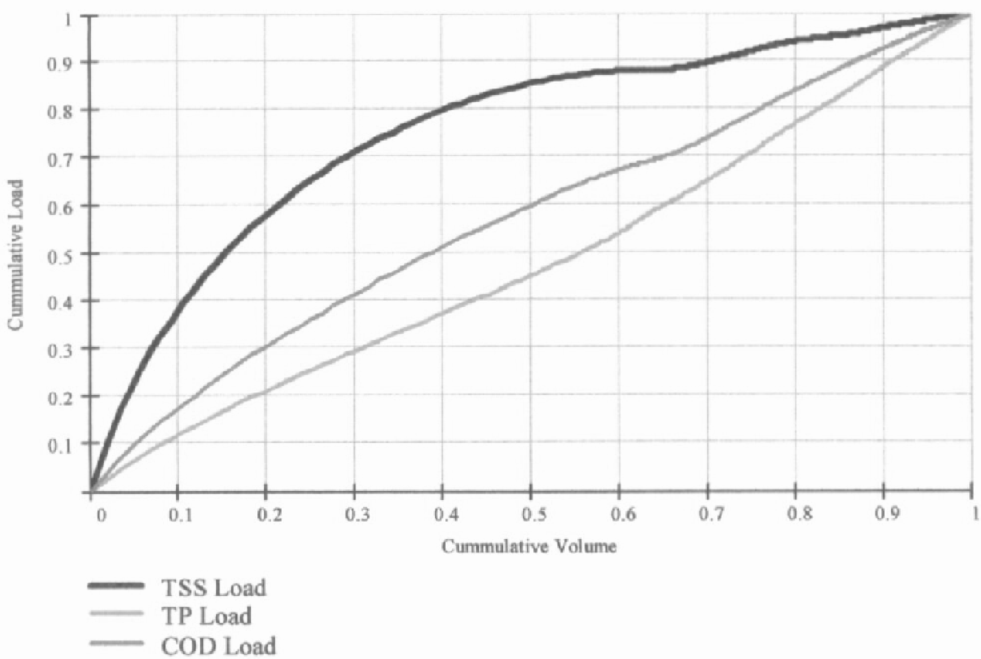


Figure 30: Cumulative Load versus Cumulative Volume Site 1 3-6-98

Appendix G contains the graphs of the cumulative loads. Various rain events were chosen to illustrate the comparison of cumulative flow versus cumulative pollutant load at 25%, 50%, and 75% of the discharge flow. Table 20 located on the next page, compares these rain events and flows.

Table 20: Cumulative Load vs. Cumulative Volume

Site 1 (Commercial)	25% Flow			50% Flow			75% Flow		
Rain Event	TSS	COD	TP	TSS	COD	TP	TSS	COD	TP
3/6/98	65	35	25	74	48	62	95	70	86
3/17/98	48	26	32	73	48	62	94	86	70
1/9/99	51	25	27	70	49	56	83	72	77
3/25/99	47	50	51	74	75	78	93	91	92
7/8/99	36	33	30	63	58	58	89	82	82
12/6/99	35	36	40	68	68	68	92	90	91
Average	**47**	**34**	**34.17**	**70.33**	**57.67**	**64.00**	**91**	**81.83**	**83**
Site 2 (Wetland)	**25% Flow**			**50% Flow**			**75% Flow**		
Rain Event	TSS	COD	TP	TSS	COD	TP	TSS	COD	TP
3/6/98	8	20	16	43	35	43	77	65	75
3/17/98	5	15	12	28	43	38	75	76	73
1/9/99	29	29	32	73	60	60	86	81	83
3/25/99	43	30	35	75	52	67	90	76	87
7/8/99	40	32	32	72	53	58	88	80	81
12/6/99	16	23	10	39	48	35	67	73	66
Average	**23.5**	**24.8**	**22.8**	**55**	**48.5**	**50.17**	**80.5**	**79**	**77.5**
Site 3 (Residential)	**25% Flow**			**50% Flow**			**75% Flow**		
Rain Event	TSS	COD	TP	TSS	COD	TP	TSS	COD	TP
3/6/98	55	23	35	78	50	57	90	73	75
3/17/98	35	32	32	73	52	52	90	73	75
1/9/99	18	27	28	63	52	55	88	80	78
3/25/99	45	23	33	68	48	55	88	72	83
7/8/99	25	28	27	51	52	52	77	75	77
12/6/99	47	26	8	72	52	38	89	75	70
Average	**37.5**	**26.5**	**27.17**	**67.5**	**51**	**51.5**	**87**	**74.67**	**76.33**
Site 4 (Construction)	**25% Flow**			**50% Flow**			**75% Flow**		
Rain Event	TSS	COD	TP	TSS	COD	TP	TSS	COD	TP
3/6/98	2	11	10	50	40	37	85	73	73
3/17/98	15	22	15	38	45	57	55	65	75
1/9/99	18	27	28	72	58	58	88	82	79
3/25/99	64	38	38	85	58	62	95	80	86
7/8/99	23	15	35	58	48	69	85	80	88
12/6/99	43	40	17	72	61	63	92	81	84
Average	**27.5**	**26.5**	**23.83**	**62.60**	**51.67**	**57.67**	**83**	**76.83**	**80.83**

The average for the rain events is used to illustrate the percentage of pollutant loads being discharged in the percentage of volume of runoff. Twenty-five percent of the volume of flow at Site 1 (Commercial) contains 47% of the pollutant load for Total Suspended Solids, 34% for COD, and 34% for Total Phosphorus. Site 2 (Wetland) had 23 – 25% of the pollutants in 25% of the volume of flow. Site 3 (Residential) ranged from 27-38% of the pollutant load in 25% of the volume of runoff. Site 4 (Construction) had 24-28% of pollutant load transported in 25% of the volume of flow. At 50% flow Total Suspended Solids for the sites ranged from 55-70% of pollutants in the flow, COD 48-58%, Total Phosphorus 50-64%. At 75% of flow Total Suspended Solids ranged from 81-91%, COD 75-82%, and Total Phosphorus 76-83% of the pollutant load discharged.

Based on the comparison of sites, Sites 1 and 3 illustrated more of the "first flush" effect than Sites 2 and 4. Site 4 (Construction) had a higher percentage of pollutants in the flow than did Site 2. This suggests that the wetland may not exhibit "first flush".

Land Use Comparison

One of the objectives of this research project is to compare pollutants discharged from the four different types of land use. This information is valuable for designing an effective pollution prevention program based on land use type. Comparison of pounds of pollutants discharged per acre of landmass per inch of rain was performed by summing the total pounds discharged per site. The data was divided up into four categories: 1.) Overall Project, 2.) 1998, 3.) 1999, 4.) March –December 1999. For the overall project Site 3 (Residential) discharged more total pounds of COD than the other sites, 58.6 pounds, Site 1 (Commercial) discharged 48.4 pounds, Site 2 (Wetland) and Site 4

(Construction) were basically the same, 38.4 and 38.9 pounds, respectively. Table 21 illustrates these comparisons. Site 2 and 4 discharged approximately the same poundage for Total Suspended Solids in the overall project category. After the dredging Site 2 (Wetland) had dropped to less than half of Site 4 (Construction).

Site 3 (Residential) discharged the least amount of total pounds of pollutants in 1999, but in 1998, discharged more for some of the parameters. Site 2 (Wetland) was third out of the four sites. Site 1 (Commercial) discharged more total pounds of pollutants than the other sites in 1999, whereas; in 1998 it discharged the least.

Based on overall poundage Sites 2 and 4 had more pollutants discharged for Total Phosphorus, Total Suspended Solids, and NH_3 than Sites 1 and 3. After the dredging occurred, Site 2 (Wetland) discharged about half the amount of pounds for each pollutant than Site 4 (Construction), whereas; in 1998 Site 2 (Wetland) discharged more than Site 4 (Construction). Refer to Figures 31-35 for the graphical comparisons.

Statistics

Statistical analysis was performed to determine if any trends or predictions could be made about the data. The pounds per inch rain per acre of land use from each rain event were used for the data set. Analytical and statistical calculations were performed using Excel® and Mathcad software.

The mean, median, standard deviation, and the 10 and 90 percentile values were analyzed to see if the data looked normally distributed. The mean and median for the parameters of COD, Total Suspended Solids, Total Phosphorus, NH_3 and NO_3 were not identical on all the data sets. This indicates the data distribution is not symmetrical.

Table 21: Site Comparisons for Pounds/Inch Rain/Acre

Total Pounds/Acre/Inch Rain discharge from Start of Project

	Site 1	Site 2	Site 3	Site 4
Total Phosphorus	0.481	0.835	0.511	0.673
Total Suspended Solids	419	868	394	889
COD	48.39	38.44	58.62	38.85
NO_3	6.078	5.934	6.260	5.091
NH_3	0.512	1.015	0.525	0.831

Total Pounds/Acre/Inch Rain discharge in 1998

	Site 1	Site 2	Site 3	Site 4
Total Phosphorus	0.120	0.485	0.279	0.284
Total Suspended Solids	122	539	316	373
COD	15.040	24.100	40.669	20.990
NO_3	0.627	1.594	1.675	0.709
NH_3	0.097	0.801	0.276	0.591

Total Pounds/Acre/Inch Rain discharge in 1999

	Site 1	Site 2	Site 3	Site 4
Total Phosphorus	0.361	0.349	0.232	0.409
Total Suspended Solids	298	330	78	515
COD	33.347	14.338	17.946	17.862
NO_3	5.452	4.340	4.585	4.382
NH_3	0.415	0.215	0.249	0.240

Total Pounds/Acre/Inch Rain discharged from April to Dec 1999

	Site 1	Site 2	Site 3	Site 4
Total Phosphorus	0.343	0.226	0.173	0.378
Total Suspended Solids	279	197	61	467
COD	31.70	8.94	13.18	16.26
NO_3	5.352	3.869	4.569	4.275
NH_3	0.4088	0.1847	0.2397	0.2313

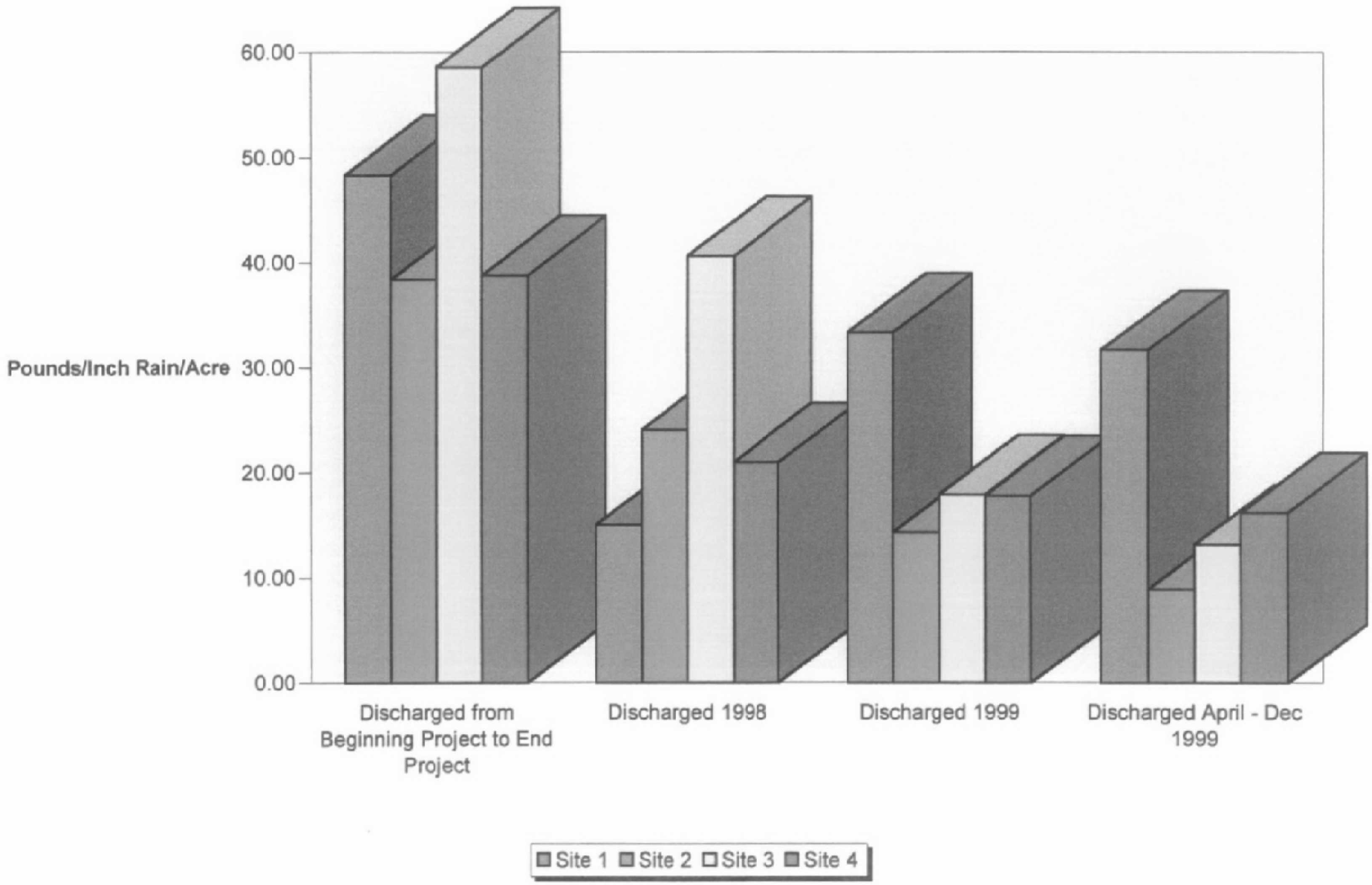


Figure 31: Land Use Comparison COD Pounds/Inch Rain/Acre

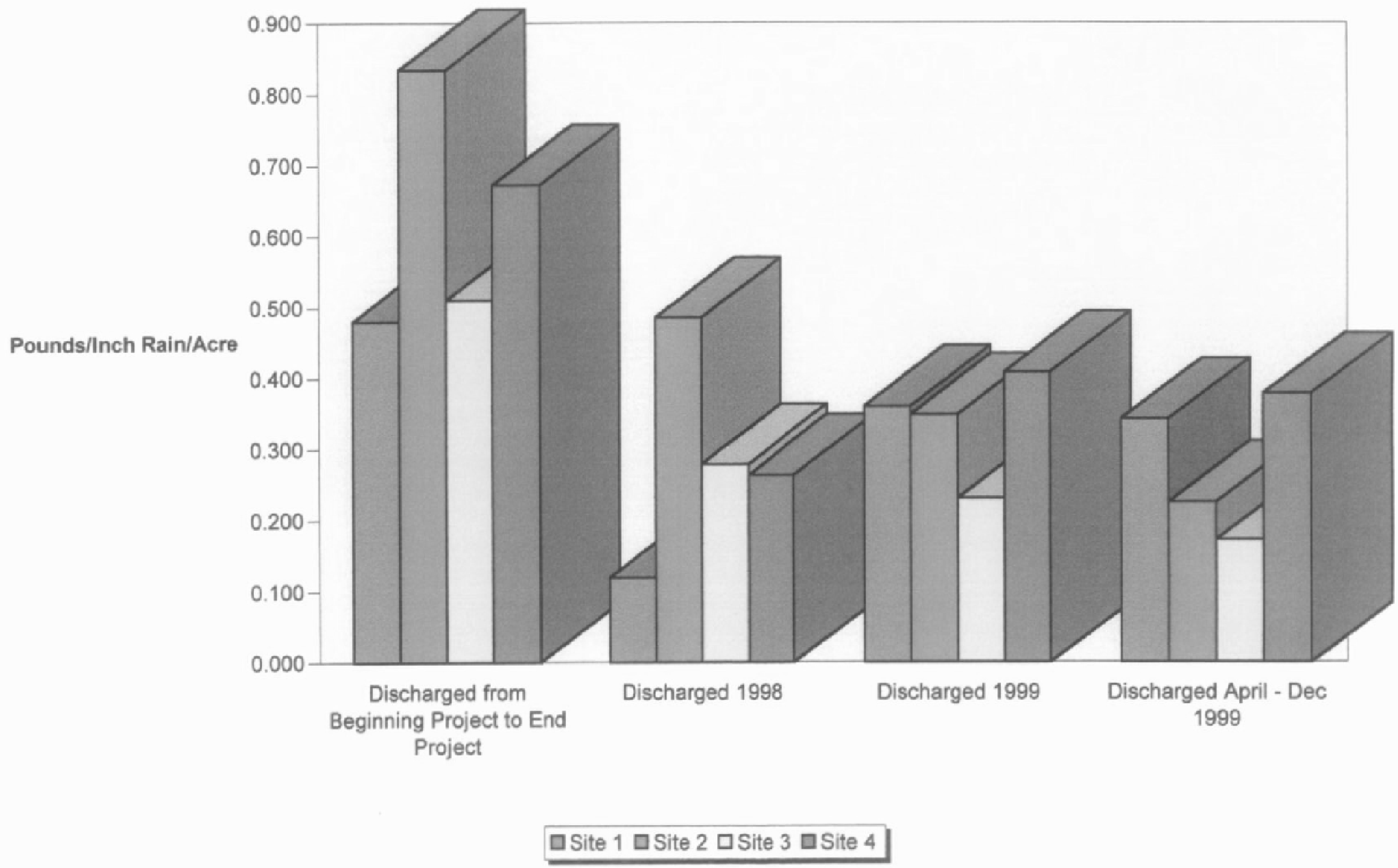


Figure 32: Land Use Comparisons TP Pounds/Inch Rain/Acre

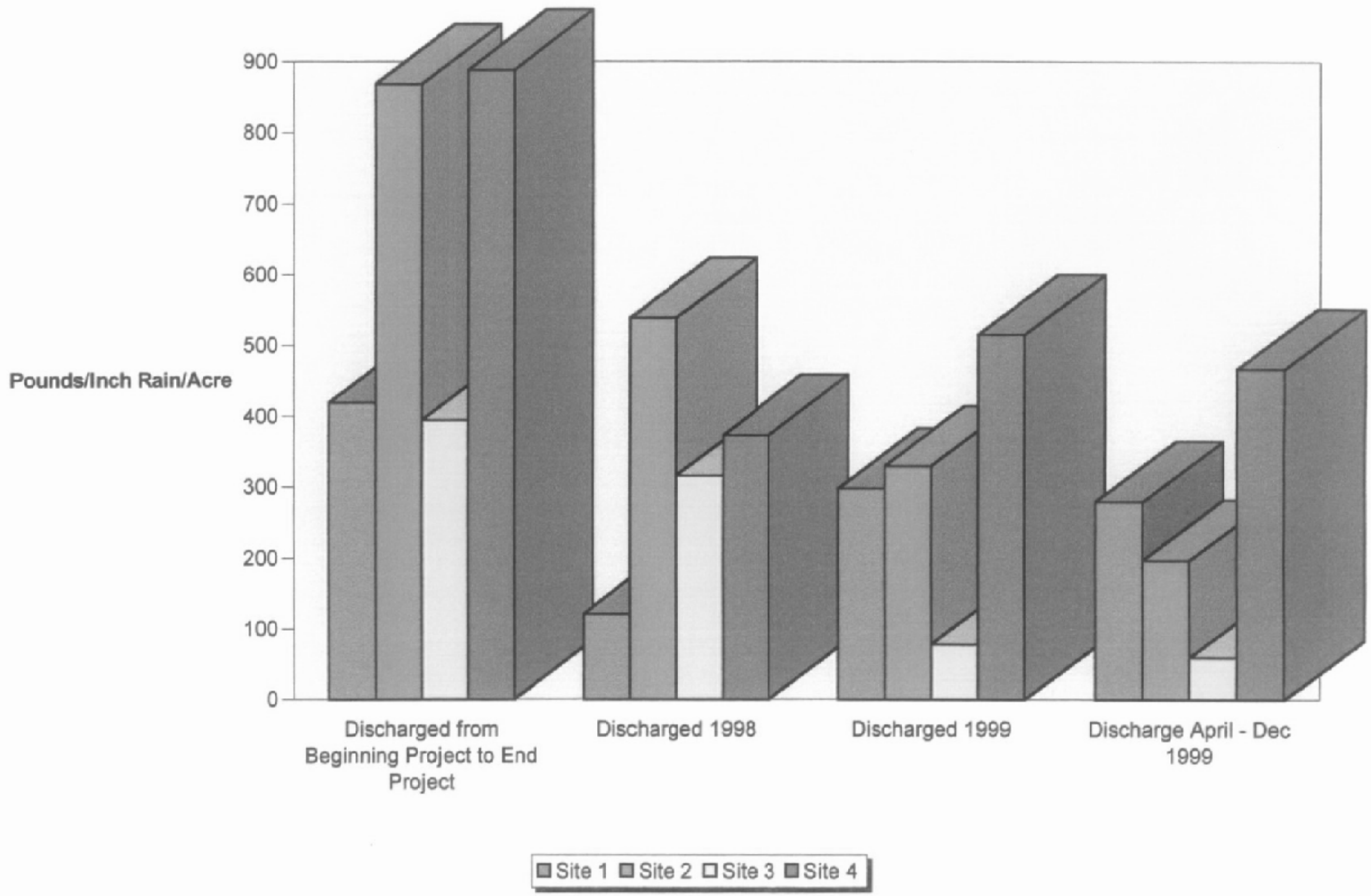


Figure 33: Land Use Comparison TSS Pounds/Inch Rain/Acre

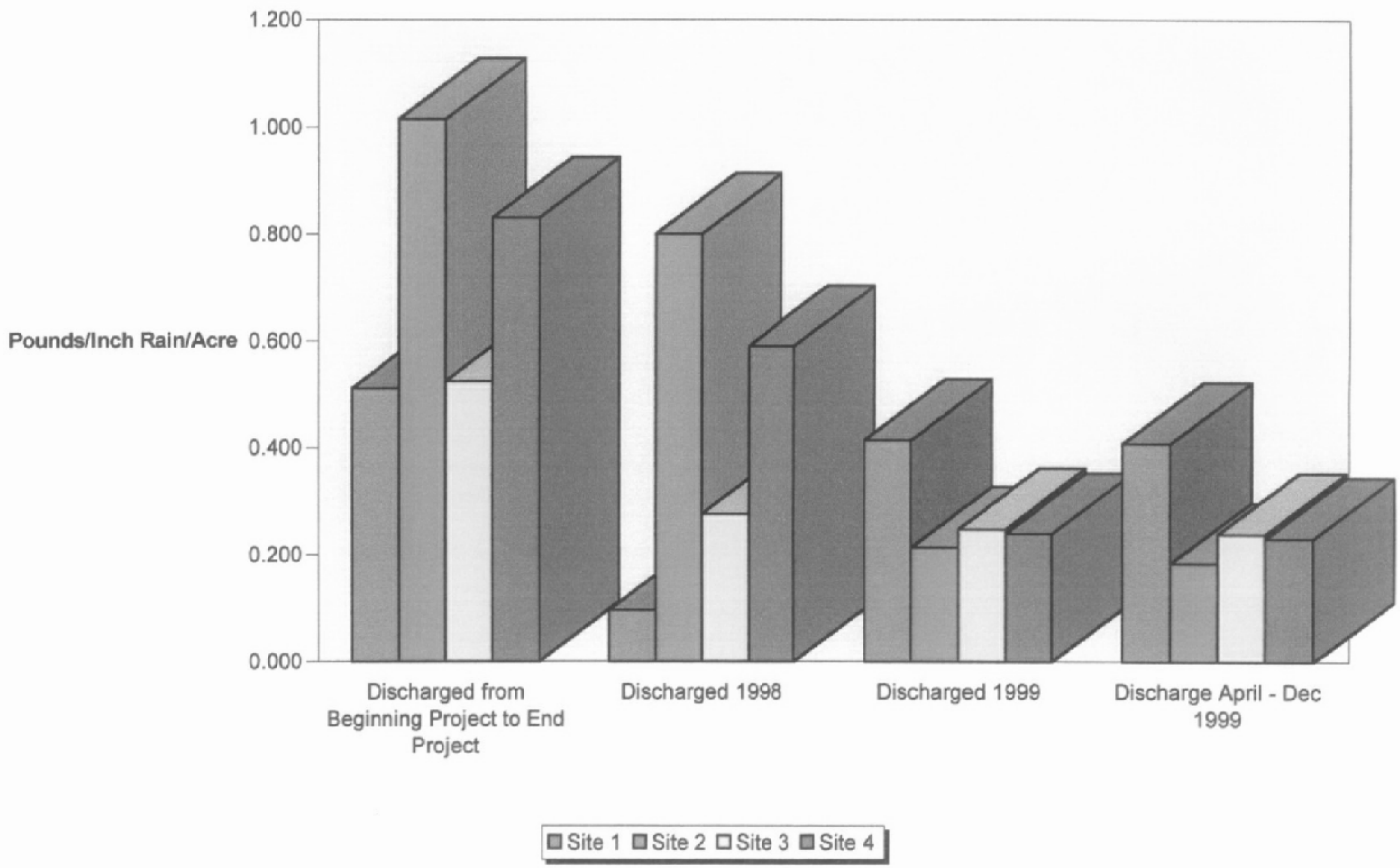


Figure 34: Land Use Comparison NH_3 Pounds/Inch Rain/Acre

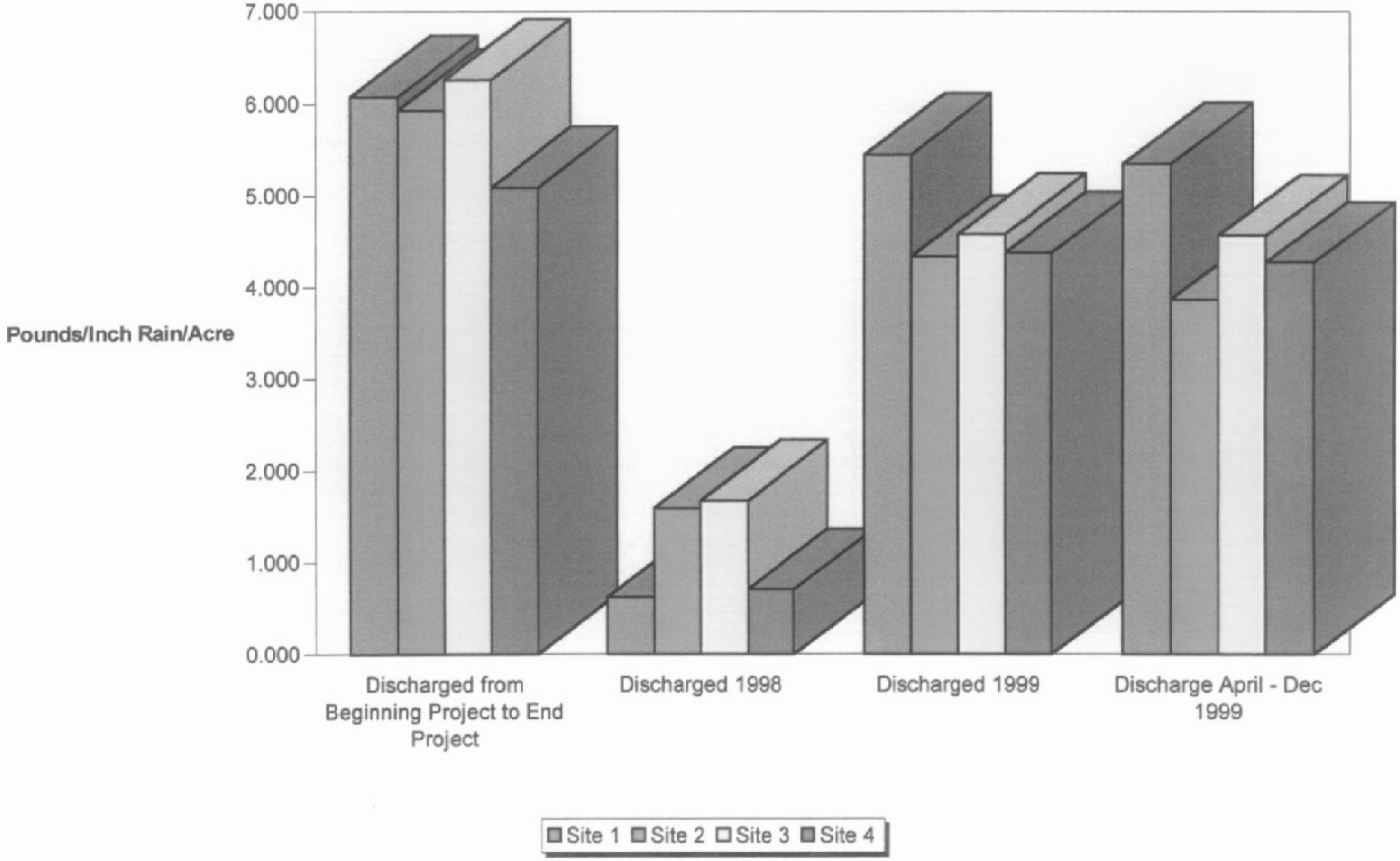
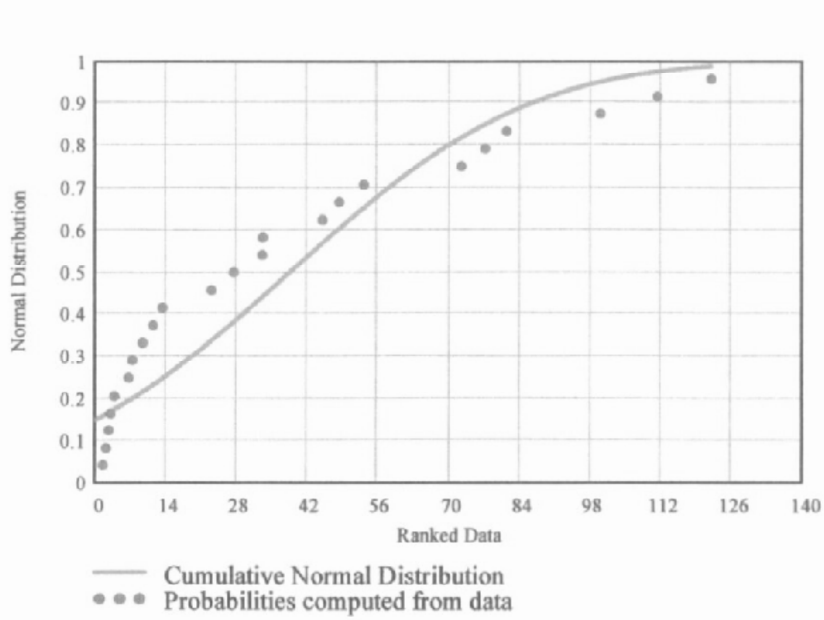


Figure 35: Land Use Comparison NO_3 Pounds/Inch Rain/Acre

By plotting the ranked data values against their corresponding probabilities a reference distribution is produced. To see if the data is normally distributed a cumulative normal distribution was plotted along with the reference distribution. COD on all the sites had no resemblance to a normal distribution. Total Suspended Solids Site 4 (Construction) more closely resembled a normal distribution; the other sites did not. Total Phosphorus on all the sites resembled a normal distribution. Appendix H contains the cumulative normal distributions.

Nonpoint pollution data typically does not follow a normal distribution, but does follow a log normal distribution. A cumulative log normal distribution was plotted versus the ranked data. All the sites for the pollutants tested appeared to follow a log normal distribution, except Site 1 (Commercial) COD and Site 4 (Construction) Total Suspended Solids. Site 4 (Construction) Total Suspended Solids followed the log normal distribution for the lower ranged values, but the upper range values were away from the curve, Figure 36 illustrates this. Site 1 (Commercial) COD had a few data points on the curve, but most were off the curve, Figure 37 illustrates this. In general the data appears to be log normally distributed, so predictions could be made about the data.

The Kruskal-Wallis and Mann-Whitney tests were used to see if the populations, or sites, were different from each other. The Kruskal-Wallis compared the sites to see if they came from identical distributions. Figure 38 shows that for Total Suspended Solids there is no difference between the sites, they have identical distribution.



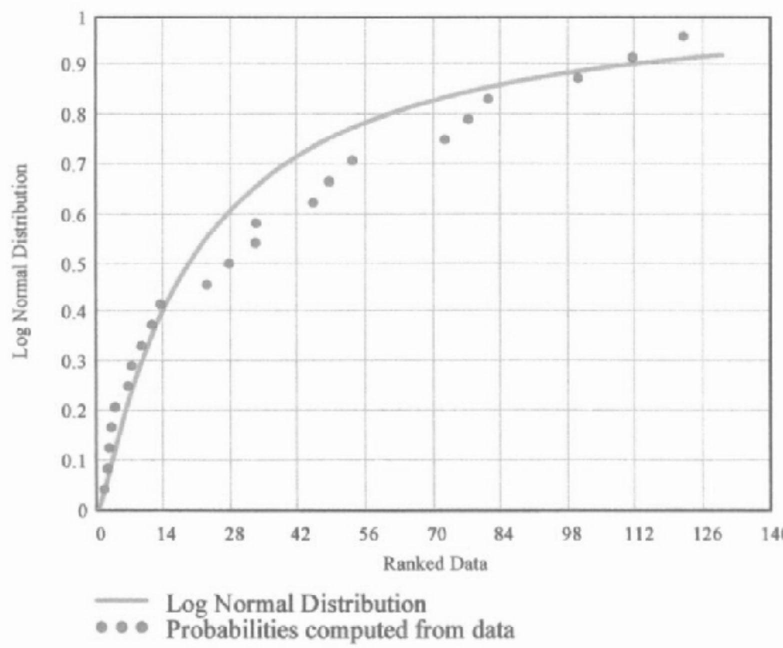


Figure 36: Site 4 TSS Normal and Log Normal Distribution

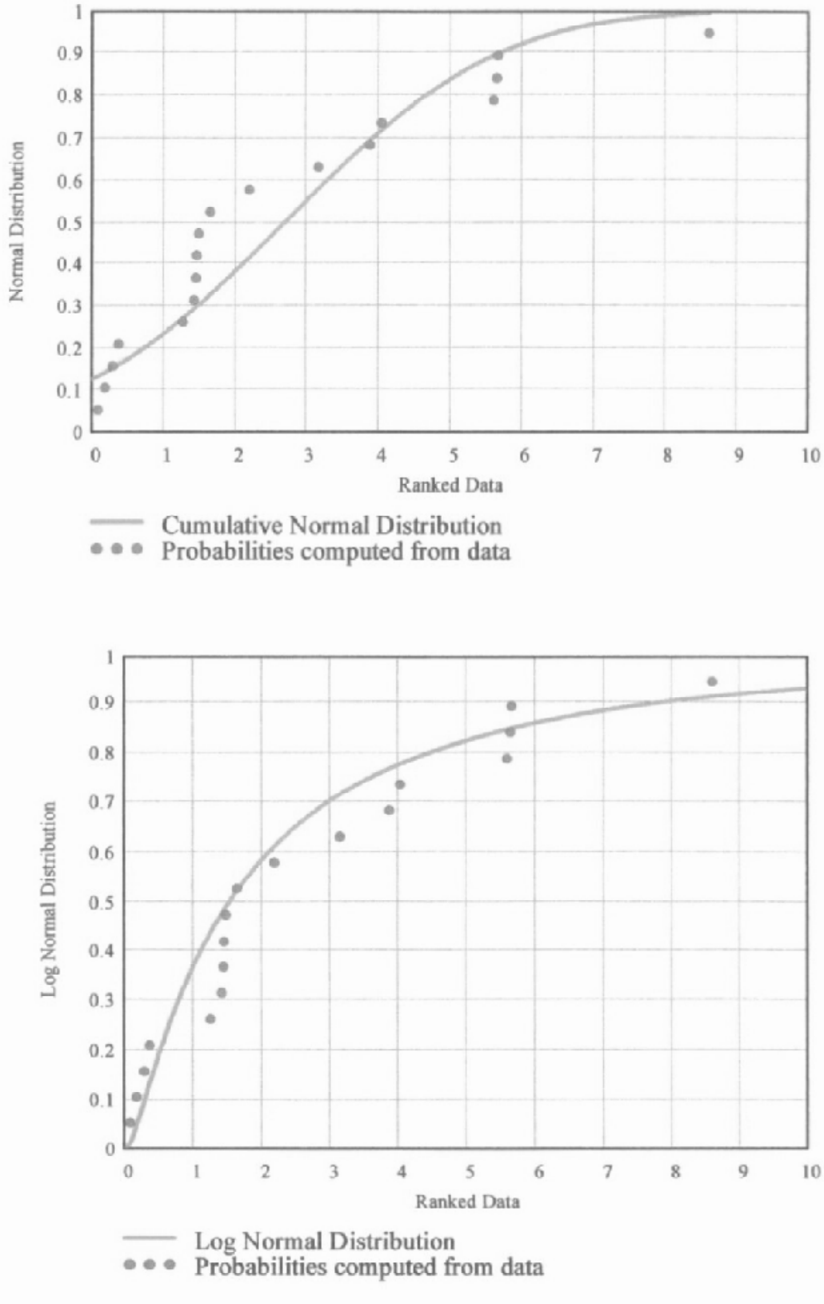


Figure 37: Site 1 COD Normal and Log Normal Distribution

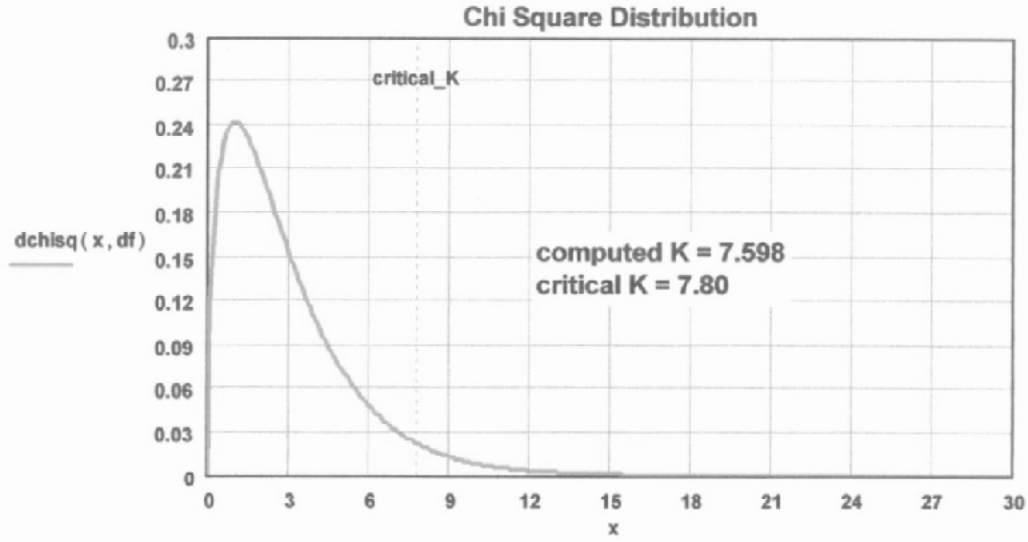


Figure 38: Kruskal-Wallis TSS Comparison

Note that the chi-square is not much greater than K, which is the computed statistic. The chi-square value is the critical value or the rejection value. If K were greater than chi-square the hypothesis would be rejected and the sites would be from different populations. Comparison of all the parameters using the Kruskal-Wallis test showed there was no difference between the sites, they all had identical distributions.

The Mann-Whitney test compared two populations, or sites, to see if the data sets equaled each other, refer to Table 22.

Table 22: Mann-Whitney Analysis

	TSS	TP	COD	NH3	NO3
1 to 2	0.394	0.85	1.34	0.016	0.66
1 to 3	1.95	0.017	0.122	0.615	0.104
1 to 4	1.13	0.439	1.66	0.016	1.53
2 to 3	1.98	0.938	1.203	0.62	0.423
2 to 4	0.488	0.552	0.329	0.075	1.17
3 to 4	2.45	0.299	1.425	0.563	1.479

* critical z value for 2-sided test with $\alpha = 0.05 = 1.96$

There were no differences between the sites for the parameters tested, except for Total Suspended Solids. The critical value, which is the value that determines if the hypothesis is accepted or rejected, is 1.96. From the table above all z values were less than 1.96 except for comparison of Sites 3 and 4 and Sites 2 and 3 for Total Suspended Solids. Site 1 and 3 comparison was so close to the z value that one could confidently reject the hypothesis. From the analysis Site 3 is from a different population than the other sites based on the Mann-Whitney analysis.

Conclusions

Extensive sediment transport resulting from various clearing and construction activities limited the amount and quality of the data that was collected. There was no removal of pollutants during the construction activities on the project. When construction ceased and the channel was dredged, removal of pollutants increased. Pollutant removal ranged from 8% to 51% after the dredging. The small amount of data collected since the dam was constructed suggests that non-soluble pollutant removals have increased. In future projects of this type, closer attention should be paid to the effect of such construction activities on the data collection function.

Comparing land use based on pounds/inch rain/acre changes the impact of loading from Site 4 (Construction) on the wetland. When expressed in pounds of sediment passing the measuring section, Sites 2 (Wetland) and 4 (Construction) far exceed Sites 1(Commercial) and 3 (Residential). However when normalized to the catchment area and rainfall, sediment yields from the four sites are not significantly different at the 95 percentile level using a Kruskal-Wallis analysis.

Visual comparison of reference distributions to known statistical distributions suggests pollutant yields can be modeled probabilistically using log normal distributions. However, the sample sizes are small. In addition, the construction of the dam will, quite probably, change the statistical distribution of pollutant yield after the dam construction; additional data will be required.

Recommendations

- Prevent silt build up on the flowmeters.
- Implement a watershed management plan to help eliminate the transportation of silt from the land. This will improve the storage capacity of the basin plus basin efficiency.
- Continue with the current analysis of analytes.
- Collect more data for statistical evaluation.

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Appendix A
Flow and Pollutant Loads for All Monitoring Events

Table A.1: Pollutant Load for Discrete and Composite Samples

	Site 1 (Commercial)										
Date Samples Were Collected	Total Rainfall (inches)	Total Volume Rainfall (gal)	Volume of Flow (gallons)	TP (lbs Load) Discrete	TP (lbs Load) Composite	TSS (lbs Load) Discrete	TSS (lbs Load) Composite	COD (lbs Load) Discrete	COD (lbs Load) Composite	NO_3 (lbs Load) Composite	NH_3 (lbs Load) Composite
2/1/98		-									
2/3/98		-	348,000		0.25		96		18	1.6	0.23
2/7/98		-									
2/11/98	1.56	2,058,586	290,400			240			211		
2/15/98	0.34	448,666									
2/22/98	1.2	1,583,528									
2/23/98		-	148,000	0.292	0.33	178.56	191.32	39.39	41.97	5.67	1.28
3/6/98	2.68	3,536,546	471,000	2.35	7.07	26,950	2,836	367.48	349.6	17	
3/16/98		-									
3/17/98	2.4	3,167,056	399,700	1.752	2.43	1,430	1,070	148.864	156.67	4	
4/15/98		-									
4/18/98		-									
4/19/98	2.03	2,678,801	48,500		0.19		68		14	2.22	0.86
6/5/98	0.49	646,607									
6/5/98		-									
6/7/98	1.42	1,873,841									
6/7/98		-									
7/23/98	0.55	725,784	46,460	0.19	0.15	1,129	1,127	98	80	2.06	1.08
7/27/98	2.13	2,810,782	153,931	0.722	0.74		1,971	482	381	5.85	1.03

Table A.1(continued): Pollutant Load for Discrete and Composite Samples

				Site 1 (Commercial)							
Date Samples Were Collected	Total Rainfall (inches)	Total Volume Rainfall (gal)	Volume of Flow (gallons)	TP (lbs Load) Discrete	TP (lbs Load) Composite	TSS (lbs Load) Discrete	TSS (lbs Load) Composite	COD (lbs Load) Discrete	COD (lbs Load) Composite	NO_3 (lbs Load) Composite	NH_3 (lbs Load) Composite
8/10/98	0.96	1,266,822	21,336	0.044	0.044	663	407	1.89	1.78	0.88	0.27
8/13/98	1.52	2,005,802	130,830	0.259	0.21		709	19.34	8.7	2.14	0.48
9/12/98	5.46	7,205,052	122,081	0.335		4139	6055	70.3	69	2.12	0.34
9/13/98	2.11	2,784,370	312,543		1.23		1387		73	2.6	0.86
9/14/98	0.81	1,068,881									
11/8/98	2.03	2,678,801	156,320		0.22		2185		69		0.98
11/13/98	0.58	765,372	4,581		0.01		64		2.5		0.08
12/11/98	4.83	6,373,700	53,818	0.449	0.53	664	967	29	54	3.16	0.606
12/19/98	0.97	1,280,018	17,318				85				
1/9/99	1.88	2,480,860	141,659	0.735	0.9	956	973	64.5	84	4.46	0.28
3/1/99	0.85	1,121,666	19,101	0.102	0.13	48	40	7.5	7.6	7	0.52
3/3/99	0.63	831,352	54,781	0.471	0.43	706	538	27	40	7.79	0.28
3/25/99	0.89	1,174,450	77,165	0.326	0.46	1737	1519	76	58	10.71	2.12
4/15/99	2.33	3,074,683	348,500	2.9	3.12	9,670	878	363	266	63.27	6.3
5/5/99	1.16	1,530,744	70.811	0.2	0.28	782	1,477	30	40	60.8	0.25
6/14/99	1.85	2,441,272	147,106	2.65	4.45	5,652	9,243	346	413	12.7	1.61
6/23/99	1.62	2,137,763	100,758	1.35	1.93	2,959	5,015	122.5	190	7.23	1.04
7/8/99	1.44	1,900,234	147,208	0.584	0.58	569	678	47	55	10.9	2.58
9/29/99	2.39	3,153,860	435,550	3.94	3.58	7,868	403	177	265	11	0.24
12/6/99	1.15	1,517,548	109,871	0.74	0.69	872	834	43	37	0.4	<0.01

Table A.1(continued): Pollutant Load for Discrete and Composite Samples

	Site 2 (Wetland)								
Date Samples Were Collected	Volume of Flow (gallons)	TP (lbs, Load) Discrete	TP (lbs, Load) Composite	TSS (lbs Load) Discrete	TSS (lbs Load) Composite	COD (lbs Load) Discrete	COD (lbs Load) Composite	NO_3 (lbs Load) Composite	NH_3 (lbs Load) Composite
2/1/98									
2/3/98									
2/7/98	13,680,000	34.93	48.48	23,570	4,905	3,698	4,164	187	297
2/11/98									
2/15/98									
2/22/98	18,400,000		57.55	12,440	14,732	4,241	4,450	419	256
2/23/98	6,179,000	22.756	26	7,854	6,493	1,977	1,752	192	120
3/6/98	32,430,000	212.54	256.9	376,400	206,095	5,802	15,687	646	
3/16/98									
3/17/98	35,830,000	250.59	255.49	129,900	106,978	13,100	13,148	421	
4/15/98	419,425		3.16		2,236		208	23	28
4/18/98									
4/19/98	4,777,500		40.42		19,339		2,376	248	307
6/5/98	129,230		0.54		70		88	6.6	0.99
6/5/98									
6/7/98	12,797,000		134	99,950	99,790	5,949	5,603	285	118.5
6/7/98									
7/23/98	1,240,900	9	9	39,316	14,799	1,035	890	51.5	20.59
7/27/98	5,466,000	32.21	20.5		31,227	5,960	5,402	145	27

Table A.1(continued): Pollutant Load for Discrete and Composite Samples

	Site 2 (Wetland)								
Date Samples Were Collected	Volume of Flow (gallons)	TP (lbs, Load) Discrete	TP (lbs, Load) Composite	TSS (lbs Load) Discrete	TSS (lbs Load) Composite	COD (lbs Load) Discrete	COD (lbs Load) Composite	NO_3 (lbs Load) Composite	NH_3 (lbs Load) Composite
8/10/98	5,798,600	46.03	57	107,300	54,647	586	822	118.5	55.6
8/13/98	4,622,000	22.52	18.5		28,332	658	617	62	33
9/12/98	350,926		0.73		1,370			6.29	0.91
9/13/98	24,036,000		136		331,361		7216	248.6	126
9/14/98	2,057,800		9.1		2,231		523	33.6	10.3
11/8/98	3,872,625		15.8		83,328		1195		25
11/13/98	4,729,000	12	9.9	14,460	11,319	913	1,025		18.9
12/11/98	4,368,000	40	60	25,350	31,803	1,385	1,530	176	18.9
12/19/98									
1/9/99	19,990,000	163	250	224,300	218,399	8,072	10,086	790	50
3/1/99	2,657,000	24	26	22,680	30,092	1,260	1,174	332	15.73
3/3/99	1,388,000	11.87	10.3	7510	5290	256	440	68	3.8
3/25/99	3,667,000	22.88	28.75	28,780	29,512	974	917	178.7	28.44
4/15/99	13,530,000	102	113	151,200	133,829	4,489	4,852	1979	146
5/5/99	3,189,000	36	36	32,750	29,260	1,222	1,410	1955	12.8
6/14/99	1,644,000	9.6	13.85	4,866	13,354	638	727	235	4.66
6/23/99	5,264,000	24.68	21.5	55,140	32,750	2,178	2,107	342	38
7/8/99	3,992,000	57	57	49,580	21,308	1,503	1,665	491	21
9/29/99	2,555,000	19	21	18,530	6,500	883	831	67	0.51
12/6/99	3,599,000	16.5	21	12,080	14,407	899	900	10.5	3

Table A.1(continued): Pollutant Load for Discrete and Composite Samples

	Site 3 (Residential)								
Date Samples Were Collected	Volume of Flow (gallons)	TP (lbs, Load) Discrete	TP (lbs, Load) Composite	TSS (lbs Load) Discrete	TSS (lbs Load) Composite	COD (lbs Load) Discrete	COD (lbs Load) Composite	NO_3 (lbs Load) Composite	NH_3 (lbs Load) Composite
2/1/98									
2/3/98	653,841		1.39		180		114	1.85	0.44
2/7/98									
2/11/98	1,177,000			7,919			1,168		
2/15/98									
2/22/98									
2/23/98	419,290		1.47	377.86	335	121.23	133	10	6.6
3/6/98	1,155,000	5.24	19.6	28,310	8,958	724	1,570	47	
3/16/98									
3/17/98	1,013,000	3.23	3.38	1,215	760	328	329	17.7	
4/15/98									
4/18/98									
4/19/98	252,287		1.43		227		147	12.4	2.8
6/5/98									
6/5/98									
6/7/98	180,997		1.13	310	338	103	120	7.5	0.65
6/7/98									
7/23/98	61,677	0.28	0.27	278	432	18.5	18.5	3.5	1.06
7/27/98	431,652	2.6	1.26		1,801	215	252	23	1.3

Table A.1(continued): Pollutant Load for Discrete and Composite Samples

	Site 3 (Residential)								
Date Samples Were Collected	Volume of Flow (gallons)	TP (lbs, Load) Discrete	TP (lbs, Load) Composite	TSS (lbs Load) Discrete	TSS (lbs Load) Composite	COD (lbs Load) Discrete	COD (lbs Load) Composite	NO_3 (lbs Load) Composite	NH_3 (lbs Load) Composite
8/10/98	97,731	0.331	0.37	333	106	15.76	28.5	3.79	0.27
8/13/98	168,625	0.809	0.84		295	49.89	63.28	1.86	1.46
9/12/98	196,949	0.627	0.81	194	82	71.8	80	2.28	1.18
9/13/98	975,481		5.8		748		317	8.78	5.69
9/14/98	153,090		1.03		86		93	20	1.07
11/8/98	266,657		0.9		380		82		1.24
11/13/98									
12/11/98	226,945	0.99	1.49	171	187	124	144	9.5	1.17
12/19/98	164,509				189				
1/9/99	891,377	4.39	5.06	1659	1234	421	349	1.26	0.75
3/1/99	121,613	0.575	1.075	259	479	76	96	11	0.92
3/3/99	51,524	0.115	0.116	27	31	12.65	14	3.8	0.11
3/25/99	170,719	0.323	0.58	192	94	75	74	6.78	2.51
4/15/99	496,521	4.625	4.97	2,258	1,143	227	219	92.5	5.67
5/5/99	99,805	0.41	0.7	387	330	47	40	61.8	0.31
6/14/99	182,388	1.34	1.08	647	593	120	126	26	0.59
6/23/99	427,670	3.5	4.1	1,533	1,594	269	275	99	3.5
7/8/99	132,981	0.87	0.93	514	350	40	45	19.5	0.93
9/29/99	97,660		0.937		323		85	2.78	0.72
12/6/99	150,000	0.208	0.25	212	216	36	26	0.19	0.12

Table A.1(continued): Pollutant Load for Discrete and Composite Samples

	Site 4 (Construction)								
Date Samples Were Collected	Volume of Flow (million gallons)	TP (lbs, Load) Discrete	TP (lbs, Load) Composite	TSS (lbs Load) Discrete	TSS (lbs Load) Composite	COD (lbs Load) Discrete	COD (lbs Load) Composite	NO_3 (lbs Load) Composite	NH_3 (lbs Load) Composite
2/1/98									
2/3/98	17,490,000		52.5		23,193		3,647	85	3
2/7/98	14,470,000	48.21	52.7	30,200	9,534	3,753	4,465	210	284
2/11/98									
2/15/98									
2/22/98	3,500,000			7,439	5,050	936	1,313	68	71
2/23/98	3,032,000		11	2,764	1,008	744	895	144	26.5
3/6/98	20,370,000	183	236	39,000	383,602	5,056	41,027	654	
3/16/98									
3/17/98	1,527,000	1.67	3.56	2,902	4,011	467	509	22.5	
4/15/98	420,649		18.32		16,285		667	21.6	161
4/18/98									
4/19/98	2,188,000		33.76		16,533		1,445	120	198
6/5/98	123,583		0.86		535		51	1.9	5.95
6/5/98									
6/7/98	1,598,000		5.4	20,330	46,179	1,103	1,879	45	13
6/7/98									
7/23/98	582,931	2.48	2.67	20,108	3,695	151	151	24.5	10.5
7/27/98	1,901,000	10.5	15.85		75,467	4,129	4,566	94	13

Table A.1(continued): Pollutant Load for Discrete and Composite Samples

	Site 4 (Construction)								
Date Samples Were Collected	Volume of Flow (million gallons)	TP (lbs, Load) Discrete	TP (lbs, Load) Composite	TSS (lbs Load) Discrete	TSS (lbs Load) Composite	COD (lbs Load) Discrete	COD (lbs Load) Composite	NO_3 (lbs Load) Composite	NH_3 (lbs Load) Composite
8/10/98	224,682	4.02	3.5	23,920	21,306	63	49	8.13	23.8
8/13/98	544,192		1.91		6,536		77	9.17	4.18
9/12/98	7,863,000	51.9	24	121,500	66,233	3158	2098	203	85
9/13/98	8,835,000		56		182,220		3610	84	44
9/14/98	783,890		4.3		7,682		157	22	8.4
11/8/98	275,901		1.33		5,964		115		2.05
11/13/98	178,104		0.53		1,094		25		0.71
12/11/98	1,182,000	7.4	21.88	7,987	13,062	478	690	55.45	8.87
12/19/98	1,243,000				6,439				
1/9/99	4,145,000	40.8	40.8	70,020	58,768	2,093	2,178	180	12
3/1/99	149,600		0.28		7.5		27	17.5	0.5
3/3/99	1,551,000	11.38	12	11,220	13,375	426	673	84.6	6.1
3/25/99	2,218,000	10.8	26.6	31,910	35,146	1,025	943	142.99	18.4
4/15/99	8,221,000	69.8	75	167,200	162,837	3,771	4,182	1,167	81
5/5/99	3,321,000	49	42	76,430	57,194	2,006	1,496	2,216	31
6/14/99	849,276	6.2	16.8	7,058	2,961	804	822	153	23.4
6/23/99	5,172,000	84.69	95	154,400	132,552	4,064	3,709	649	43
7/8/99	4,685,000	87	80	81,610	131,090	2,572	3,321	765	41
9/29/99	3,004,000	56	57	41,410	11,725	1,510	1,478	149	4
12/6/99	2,984,000	16.4	19	41,440	42,929	983	896	9.7	2.5

Appendix B
Pounds per Inch Rain per Acre
Site Comparison

Table B.1: Total Phosphorus Site Comparison Pounds/Inch Rain/Acre

Date	Site 1(Commercial)	Site 2 (Wetland)	Site 3 (Residential)	Site 4 (Construction)
2/22/98	0.00	0.05	0.00	0.02
2/23/98	0.01	0.02	0.03	0.01
3/6/98	0.07	0.10	0.11	0.11
4/15/98	0.00	0.004	0.00	0.03
4/19/98	0.00	0.02	0.02	0.02
6/5/98	0.00	0.00	0.00	0.00
6/7/98	0.00	0.11	0.02	0.01
8/10/98	0.00	0.06	0.01	0.01
9/13/98	0.02	0.07	0.06	0.04
9/14/98	0.00	0.01	0.03	0.01
11/13/98	0.00	0.02	0.00	0.00
12/11/98	0.00	0.01	0.01	0.01
1/9/99	0.02	0.12	0.06	0.03
3/3/99	0.03	0.02	0.00	0.03
3/25/99	0.02	0.03	0.01	0.03
4/15/99	0.05	0.05	0.05	0.04
5/5/99	0.01	0.03	0.01	0.06
6/14/99	0.08	0.01	0.02	0.01
6/23/99	0.04	0.01	0.05	0.08
7/8/99	0.02	0.04	0.01	0.08
9/29/99	0.07	0.01	0.01	0.03
12/6/99	0.03	0.02	0.00	0.02

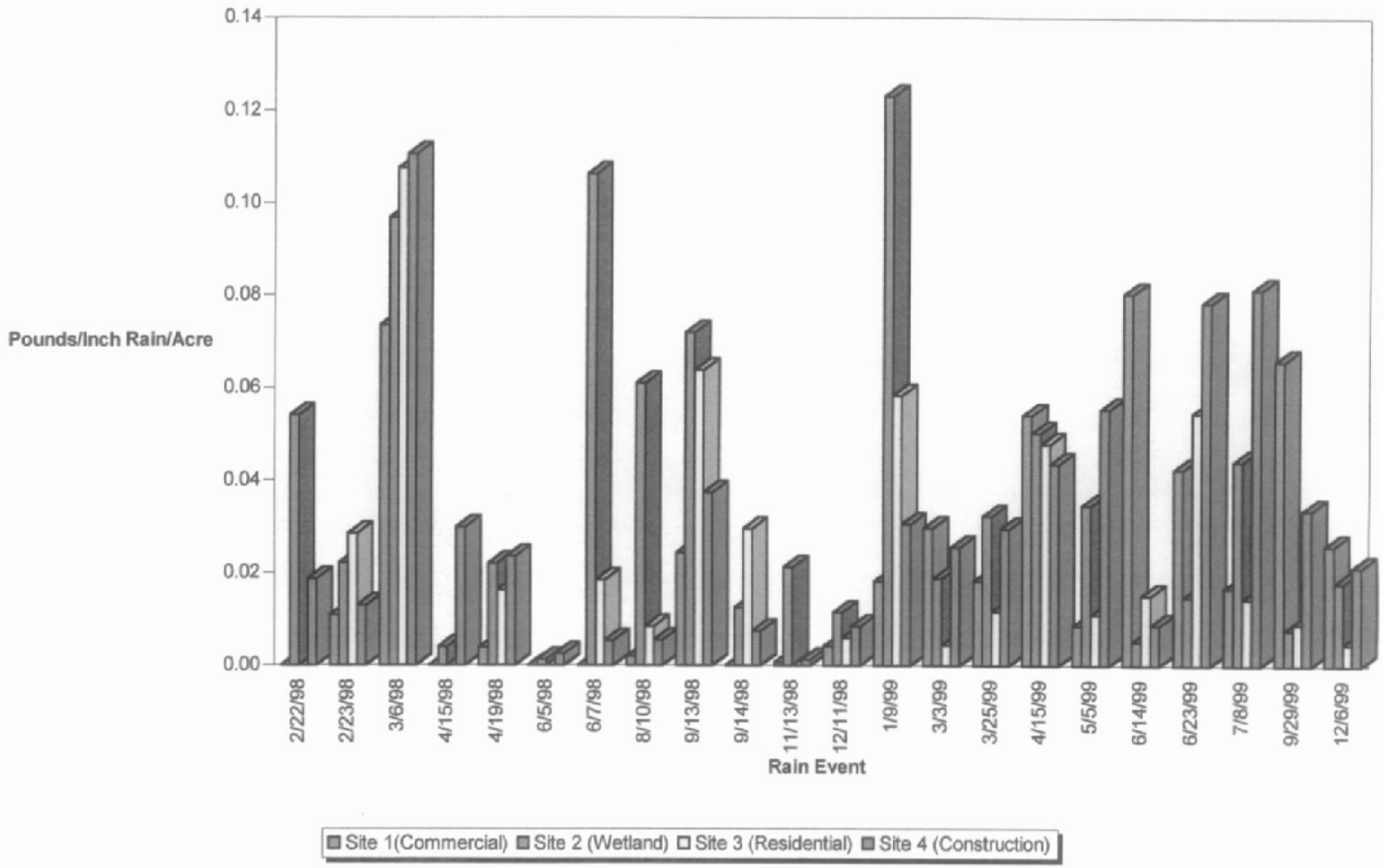


Figure B.1: Site Comparison for Each Rain Event Total Phosphorus Pounds/Inch Rain/Acre

Table B.2: Total Suspended Solids Site Comparison Pounds/Inch Rain/Acre

Date	Site 1 (Commercial)	Site 2 (Wetland)	Site 3 (Residential)	Site 4 (Construction)
2/11/98	6.4	0.0	118.1	0.0
2/22/98	0.0	12.8	0.0	7.3
2/23/98	6.5	6.6	6.9	2.2
3/6/98	73.6	120.5	161.7	111.3
4/15/98	0.0	2.8	0.0	23.0
4/19/98	3.9	10.6	2.6	11.5
6/5/98	0.0	0.2	0.0	1.5
6/7/98	0.0	79.3	5.3	33.0
8/10/98	1.9	95.0	5.3	33.2
9/13/98	24.4	176.4	8.2	121.9
9/14/98	0.0	3.1	2.5	13.4
11/13/98	0.7	25.0	0.0	2.7
12/11/98	4.2	6.6	0.9	3.1
12/19/98	0.0	0.0	4.5	9.4
1/9/99	18.3	132.2	17.9	48.3
3/3/99	29.9	10.6	1.1	27.5
3/25/99	18.4	36.4	3.7	53.2
4/15/99	54.1	67.5	17.0	99.9
5/5/99	8.7	29.9	7.2	81.3
6/14/99	80.4	3.4	7.8	3.8
6/23/99	26.2	18.2	13.9	77.2
7/8/99	11.7	19.0	4.8	72.4
9/29/99	27.6	1.7	1.3	6.6
12/6/99	22.6	10.7	3.8	45.0

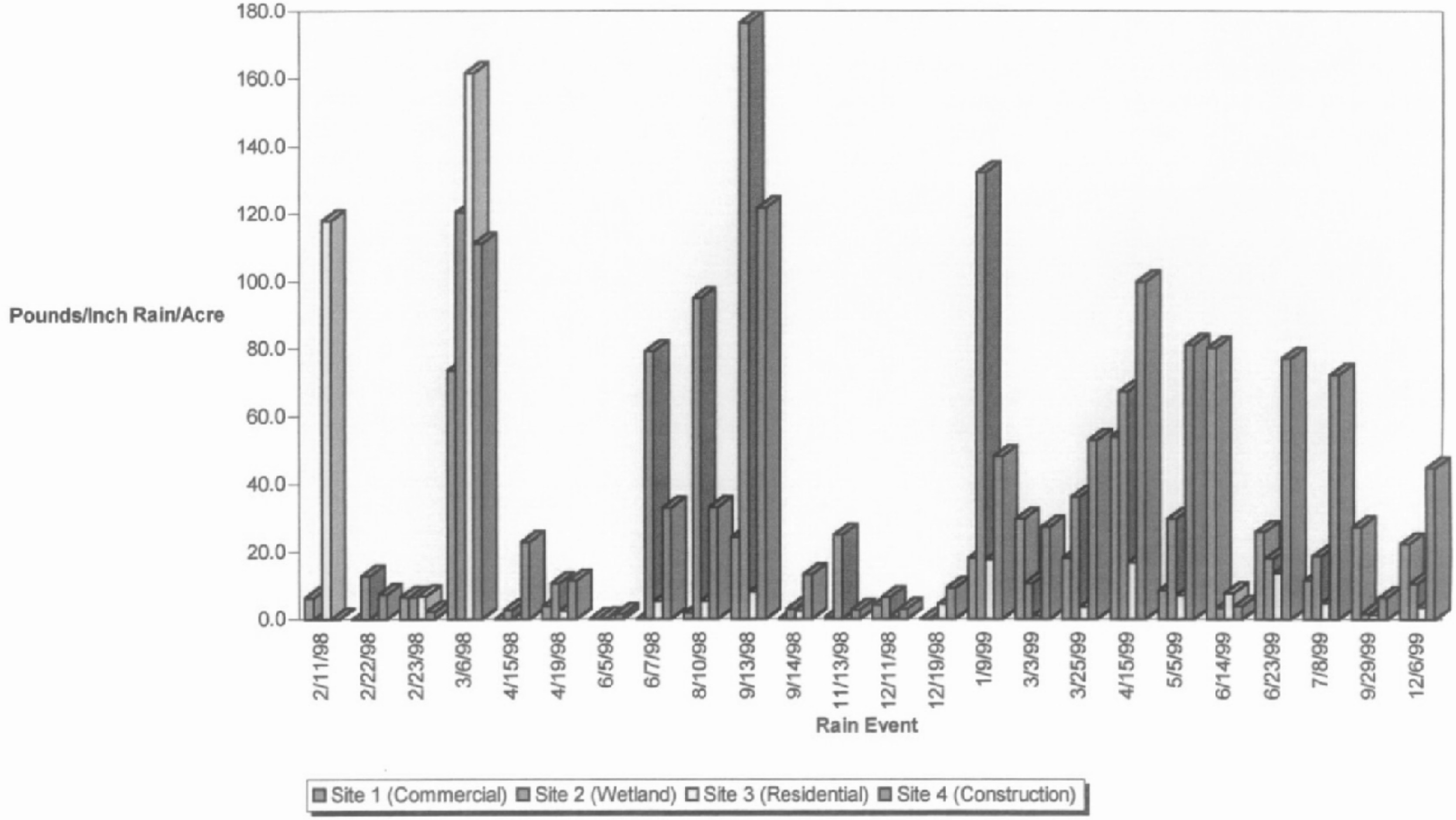


Figure B.2: Site Comparison for Each Rain Event TSS Pounds/Inch Rain/Acre

Table B.3: COD Site Comparison Pounds/Inch Rain/Acre

Date	Site 1 (Commerci	Site 2 (Wetland)	Site 3 (Residential	Site 4 (Construction)
2/11/98	5.7	0.0	17.4	0.0
2/22/98	0.0	4.1	0.0	1.3
2/23/98	1.4	1.7	2.5	1.0
3/6/98	5.6	4.4	10.0	12.1
4/15/98	0.0	0.3	0.0	0.9
4/19/98	0.3	1.3	1.7	1.0
6/5/98	0.0	0.2	0.0	0.1
6/7/98	0.0	4.6	1.8	1.5
8/10/98	0.1	0.8	0.5	0.1
9/13/98	1.4	3.8	3.5	2.4
9/14/98	0.0	0.7	2.7	0.3
11/13/98	0.2	1.9	0.0	0.1
12/11/98	0.4	0.3	0.6	0.2
1/9/99	1.6	5.4	4.8	1.6
3/3/99	2.2	0.6	0.5	1.2
3/25/99	3.2	1.1	2.0	1.6
4/15/99	5.6	2.1	2.2	2.4
5/5/99	1.3	1.2	0.9	2.1
6/14/99	8.6	0.2	1.5	0.6
6/23/99	4.0	1.4	3.9	3.4
7/8/99	1.5	1.2	0.7	2.9
9/29/99	3.9	0.3	0.8	0.9
12/6/99	1.5	0.8	0.6	1.2

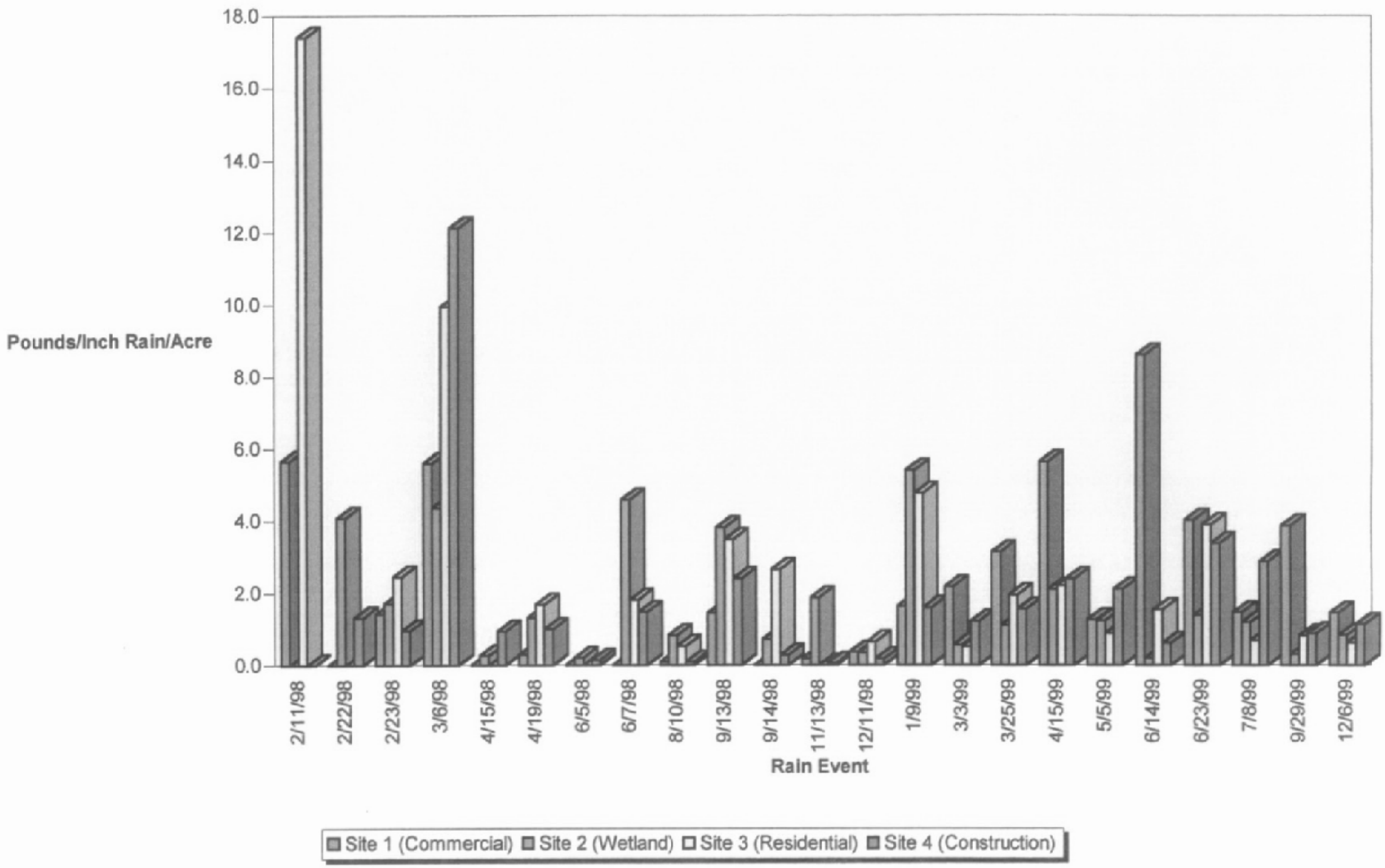


Figure B.3: Site Comparison for Each Rain Event COD Pounds/Inch Rain/Acre

Table B.4: BOD Site Comparison Pounds/Inch Rain/Acre

Date	Site 1 (Commercial)	Site 2 (Wetland)	Site 3 (Residential)	Site 4 (Construction)
2/22/98	0	0.432	0	0.171
2/23/98	0.01	0.136	0.173	0.107
6/5/98	0	1.205	0	0.056
9/12/98	0.031	0.004	0.028	0.112
12/11/98	0.018	0.045	0.045	0.019
3/25/99	0.138	0.158	0.156	0.116
6/14/99	0.71	0.57	0.146	0.005
Total	**0.907**	**2.550**	**0.548**	**0.587**

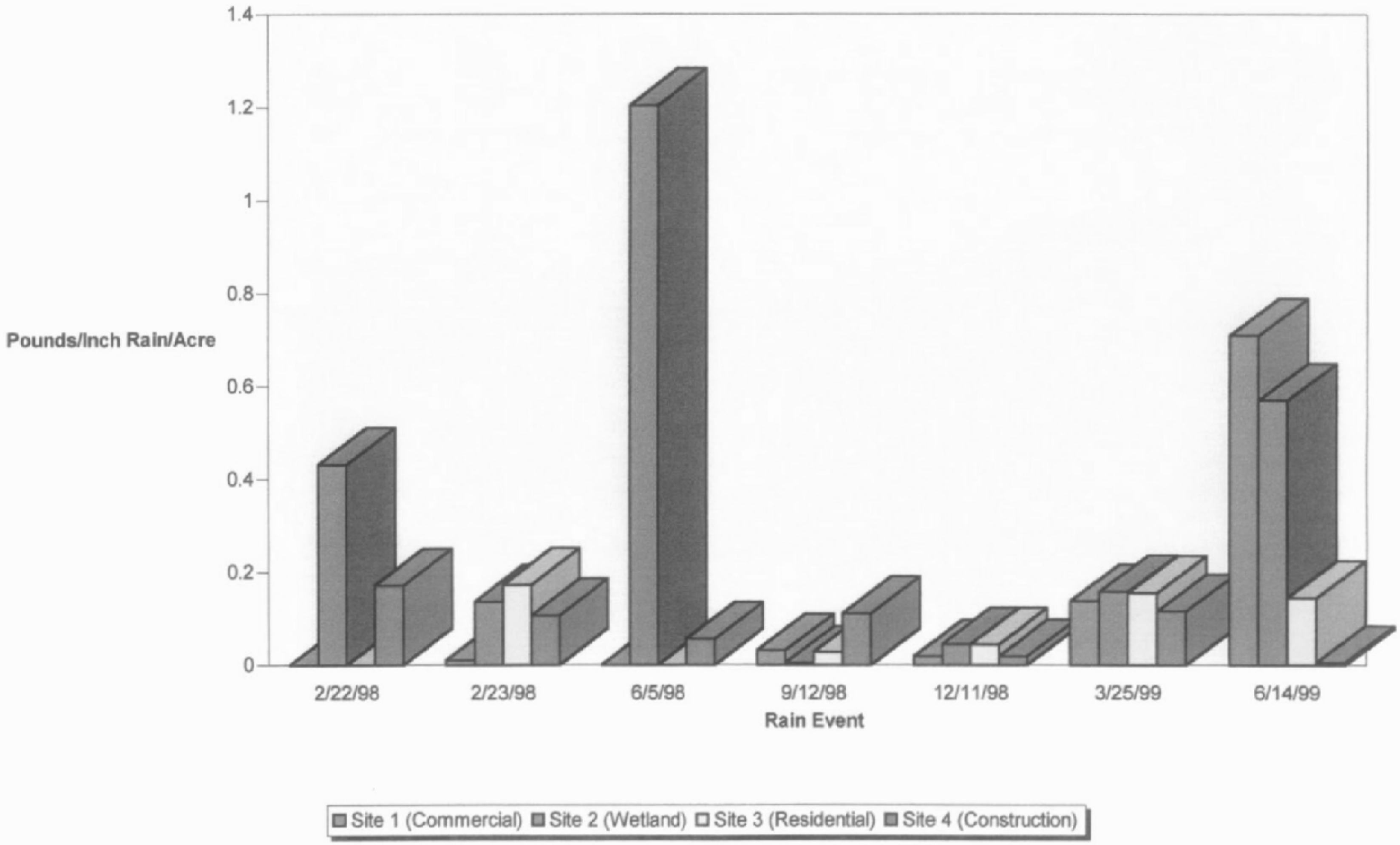


Figure B.4: Site Comparison for Each Rain Event BOD Pound/Inch Rain/Acre

Table B.5: NH_3 Site Comparison Pounds/Inch Rain/Acre

Date	Site 1 (Commercial)	Site 2 (Wetland)	Site 3 (Residential)	Site 4 (Construction)
2/22/98	0.000	0.241	0.000	0.083
2/23/98	0.045	0.112	0.128	0.031
4/15/98	0.000	0.032	0.000	0.227
4/19/98	0.018	0.170	0.032	0.138
6/5/98	0.000	0.002	0.000	0.017
6/7/98	0.000	0.094	0.011	0.012
8/10/98	0.012	0.065	0.007	0.035
9/13/98	0.017	0.067	0.063	0.029
9/14/98	0.000	0.014	0.031	0.015
12/11/98	0.005	0.004	0.006	0.003
1/9/99	0.006	0.030	0.009	0.009
3/1/99	0.026	0.020	0.025	0.001
3/3/99	0.019	0.006	0.004	0.014
3/25/99	0.100	0.033	0.066	0.029
4/15/99	0.113	0.068	0.057	0.049
5/5/99	0.009	0.012	0.006	0.038
6/14/99	0.036	0.002	0.007	0.018
6/23/99	0.027	0.026	0.050	0.037
7/8/99	0.075	0.014	0.015	0.040
9/29/99	0.004	0.000	0.007	0.002
12/6/99	0.000	0.003	0.002	0.003

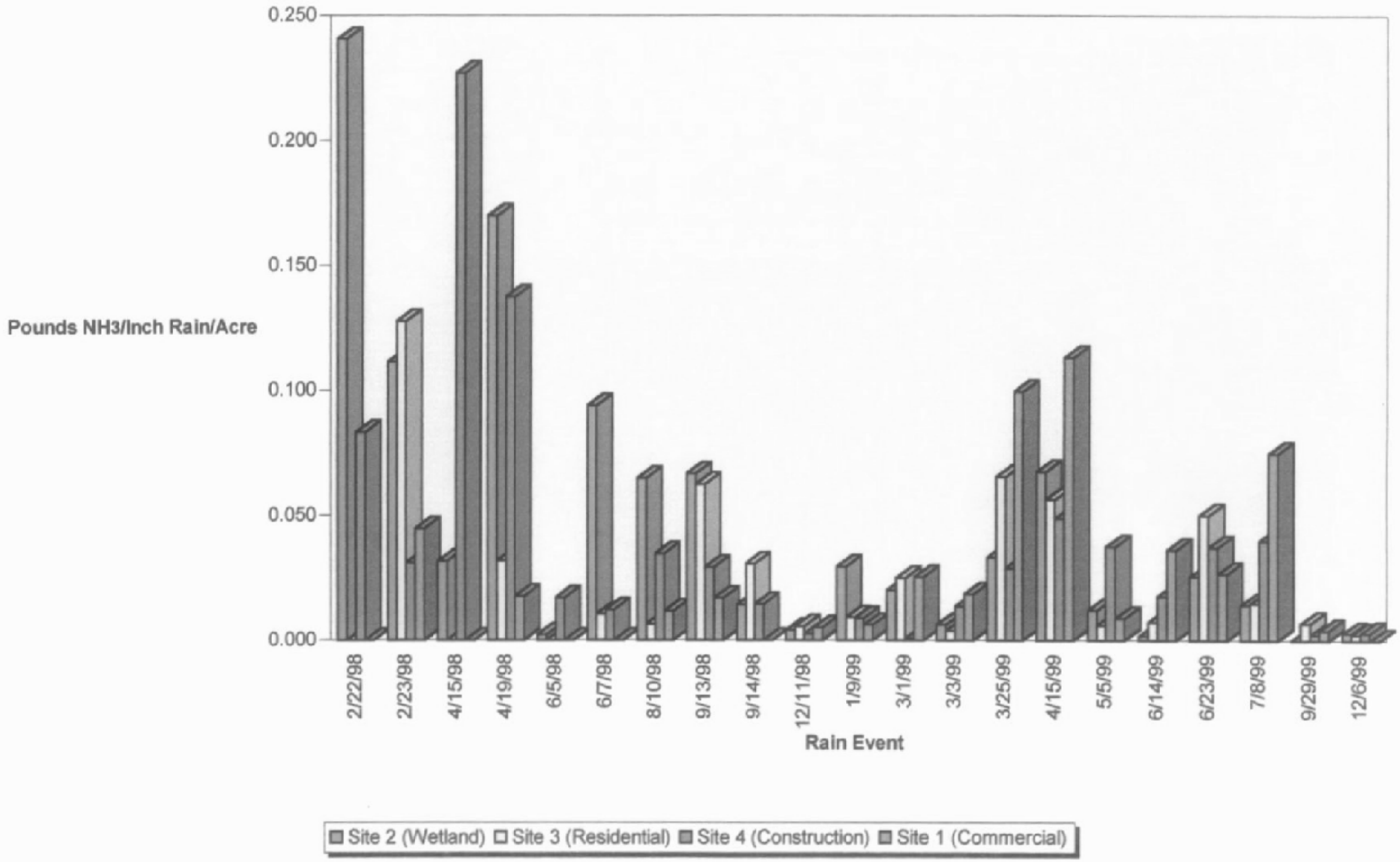


Figure B.5: Site Comparison for Each Rain Event NH_3 Pounds/Inch Rain/Acre

Table B.6: NO_3 Site Comparison Pounds/Inch Rain/Acre

Date	Site 1 (Commercial)	Site 2 (Wetland)	Site 3 (Residential)	Site 4 (Construction)
2/22/98	0.00	0.39	0.00	0.06
2/23/98	0.20	0.18	0.19	0.14
3/6/98	0.27	0.26	0.41	0.28
4/15/98	0.00	0.03	0.00	0.03
4/19/98	0.05	0.14	0.14	0.07
6/5/98	0.00	0.02	0.00	0.00
6/7/98	0.00	0.23	0.12	0.04
8/10/98	0.04	0.14	0.09	0.01
9/13/98	0.05	0.13	0.10	0.04
9/14/98	0.00	0.05	0.57	0.03
12/11/98	0.03	0.04	0.05	0.01
1/9/99	0.10	0.47	0.02	0.11
3/3/99	0.52	0.11	0.14	0.15
3/25/99	0.50	0.21	0.18	0.18
4/15/99	1.14	0.93	0.92	0.56
5/5/99	2.19	1.84	1.23	2.15
6/14/99	0.29	0.14	0.33	0.09
6/23/99	0.19	0.23	1.42	0.45
7/8/99	0.32	0.38	0.31	0.60
9/29/99	0.19	0.03	0.03	0.07
12/6/99	0.01	0.01	0.00	0.01

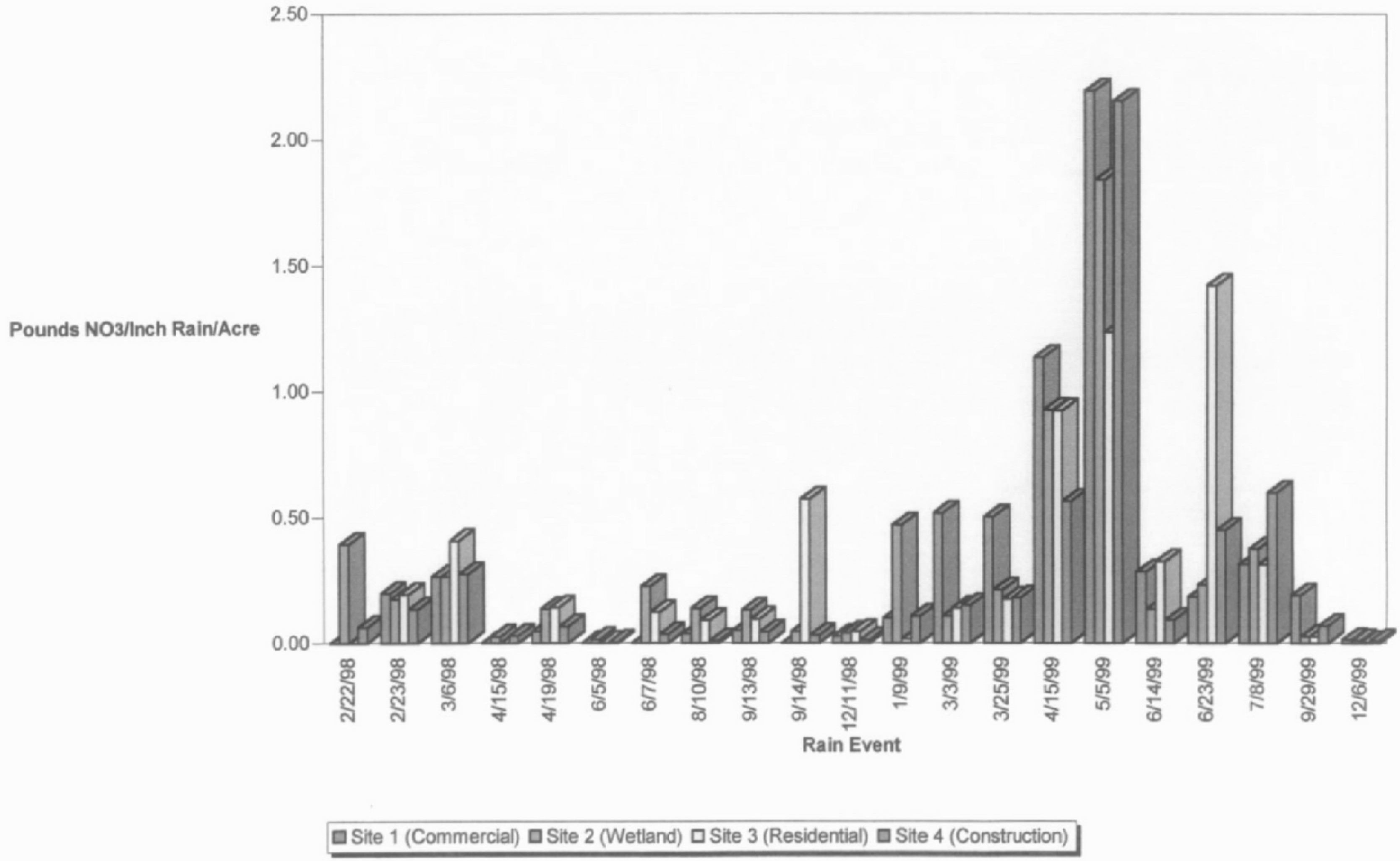


Figure B.6: Site Comparison for Each Rain Event NO_3 Pounds/Inch Rain/Acre

Table B.7: TKN Site Comparison Pounds/Inch Rain/Acre

Date	Site 1 (Residential)	Site 2 (Wetland)	Site 3 (Residential)	Site 4 (Construction)
2/22/98	0	0.144	0	0.057
2/23/98	0.004	0.052	0.181	0.041
3/25/99	0.201	0.155	0.198	0.137
6/14/99	0.185	0.033	0.051	0.029
Total	0.390	0.384	0.430	0.263

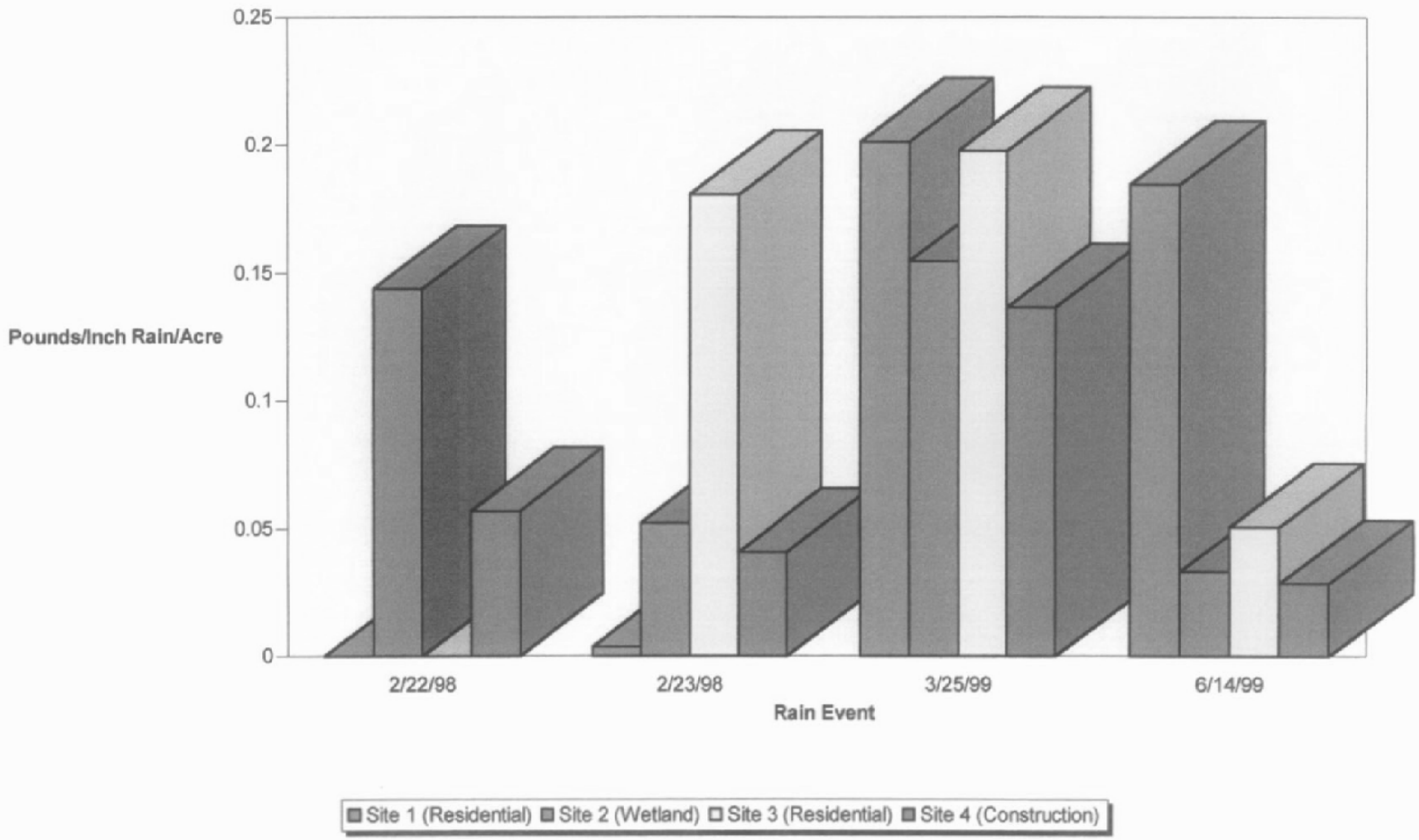


Figure B.7: Site Comparison for Each Rain Event TKN Pounds/Inch Rain/Acre

Appendix C
Mathcad Worksheet for Calculations of Mass Load

Mathcad Worksheet for Calculations of Mass Load

Flow data are contained in an ascii file called "1_1010999_TP_TSS_COD_FLOW" with the extension ".prn". Mathcad command to read that file into the worksheet is:

DATA := READPRN("1_010999_TP_TSS_COD_FLOW.prn")

File name definition:

The first number is the site from which the sample came,
The next set of six numbers are the date of sample collection,
The analytes tested for discrete analysis,
Flow,
File command.

DATA =

1.12	$5.232 \cdot 10^3$	122	64	30
0.68	$1.684 \cdot 10^3$	55	88	60
0.29	$1.387 \cdot 10^3$	80	98	149
0.79	$1.16 \cdot 10^3$	68	101	179
0.8	$1.02 \cdot 10^3$	80	89	209
0.6	527	82	66	239
0.97	690	81	52	269
0.99	$1.8 \cdot 10^3$	74	62	309
0.88	$2.43 \cdot 10^3$	13	302	339
0.65	717	46	407	369
0.82	587	48	531	399
0.57	520	51	514	429

* Note Mathcad shows 11 of the total number of rows of the above matrix at a time to conserve on space.

$i := 0..23$ number of data/rows in the matrix

Column 0 = Total Phosphorus
Column 1 = TSS
Column 2 = COD
Column 3 = Flow
Column 4 = Elapsed Time
Column 5 = Real Time-day.decimal day

DATA is divided up into six individual vectors. Each column is identified as to the contents.

Total Phosphorus: is the concentration from each discrete sample collected
Total Suspended Solids: is the concentration from each discrete sample collected
COD: is the concentration from each discrete sample collected
Flow: is the gallons per minute reading taken at sample collection time

Elapsed Time: represents the clock time that the sample was collected

Real Time-day: day and time the sample was collected in decimal day e.g 12 noon is 0.5 decimal day

[redacted]

"elasped time" or "runoff time" represents the fourth column of the matrix. It contain the interval of time between sample collection.

$$runoff\_time_i := DATA_{i,4} \cdot min$$

"Q" represents the third column of the matrix, which is flowrate at time of sample collection in gallons per minute.

$$Q_i := DATA_{i,3} \cdot \frac{gal}{min}$$

Examples of flowrate and runoff time:

$$Q = \begin{pmatrix} 64 \\ 88 \\ 98 \\ 101 \\ 89 \\ 66 \\ 52 \\ 62 \\ 302 \\ 407 \\ 531 \\ 514 \\ 415 \\ 313 \\ 235 \end{pmatrix} \cdot \frac{gal}{min} \qquad runoff\_time = \begin{pmatrix} 30 \\ 60 \\ 149 \\ 179 \\ 209 \\ 239 \\ 269 \\ 309 \\ 339 \\ 369 \\ 399 \\ 429 \\ 459 \\ 489 \\ 519 \end{pmatrix} \cdot min$$

The volume of runoff that entered the basin is the area under the hydrograph approximated by the splined curve through all individual flow measurements.

Limits of integration are the elapsed time from start to the end of runoff induced flow

$$TIME := 30 \cdot min, 31 \cdot min .. 789 \cdot min$$

$$volume := \int_{30 \cdot min}^{789 \cdot min} (interp(cspline(runoff\_time, Q), runoff\_time, Q, TIME))\, dTIME$$

The runoff volume that entered the basin is: volume = 140595 gal

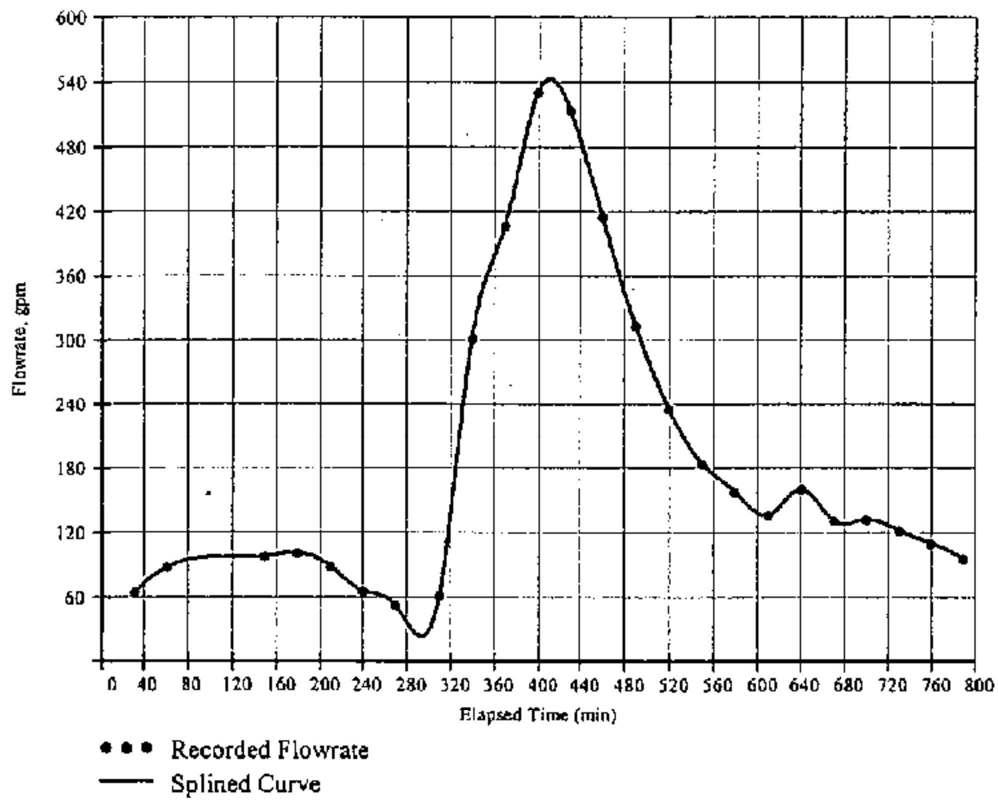


Figure C.1: Hydrograph Site 1 January 9,1999

Laboratory Test Results

Total Phosphorus-discrete sample from column zero in matrix

$TP_i := DATA_{i,0} \cdot \frac{mg}{liter}$

Total Suspended Solids-discrete sample from column 1 in matrix

$TSS_i := DATA_{i,1} \cdot \frac{mg}{liter}$

COD-discrete sample from column 2 in matrix

$COD_i := DATA_{i,2} \cdot \frac{mg}{liter}$

TP = ($\frac{mg}{liter}$)	TSS = ($\frac{mg}{liter}$)	COD = ($\frac{mg}{liter}$)
1.12	$5.232 \cdot 10^3$	122
0.68	$1.684 \cdot 10^3$	55
0.29	$1.387 \cdot 10^3$	80
0.79	$1.16 \cdot 10^3$	68
0.8	$1.02 \cdot 10^3$	80
0.6	527	82
0.97	690	81
0.99	$1.8 \cdot 10^3$	74
0.88	$2.43 \cdot 10^3$	13
0.65	717	46
0.82	587	48
0.57	520	51
0.61	473	41
0.62		57
0.26		66

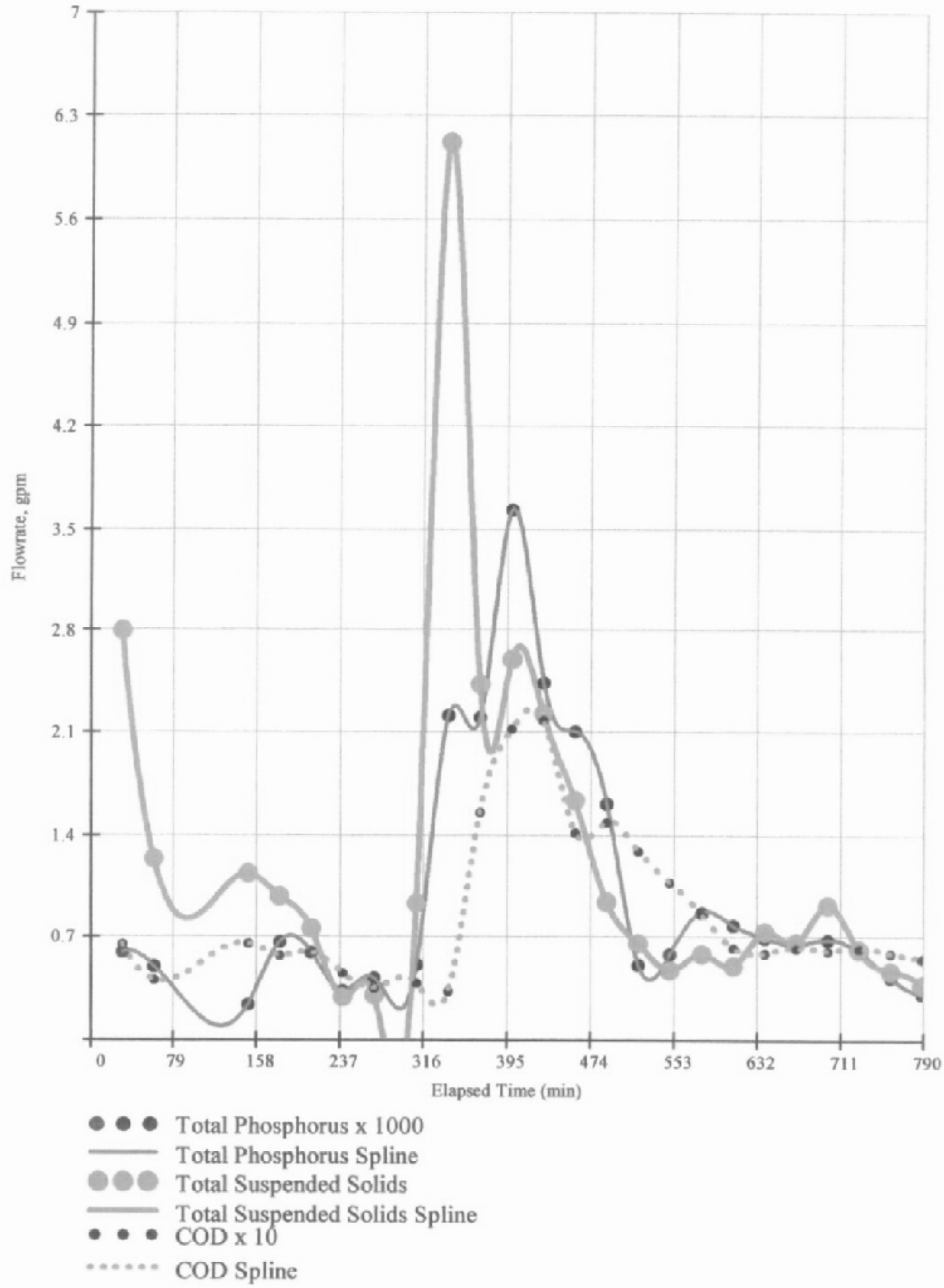


Figure C.3: Mass Load Comparison for All Sites January 9,1999

Appendix D
Hydrographs from Various Rain Events

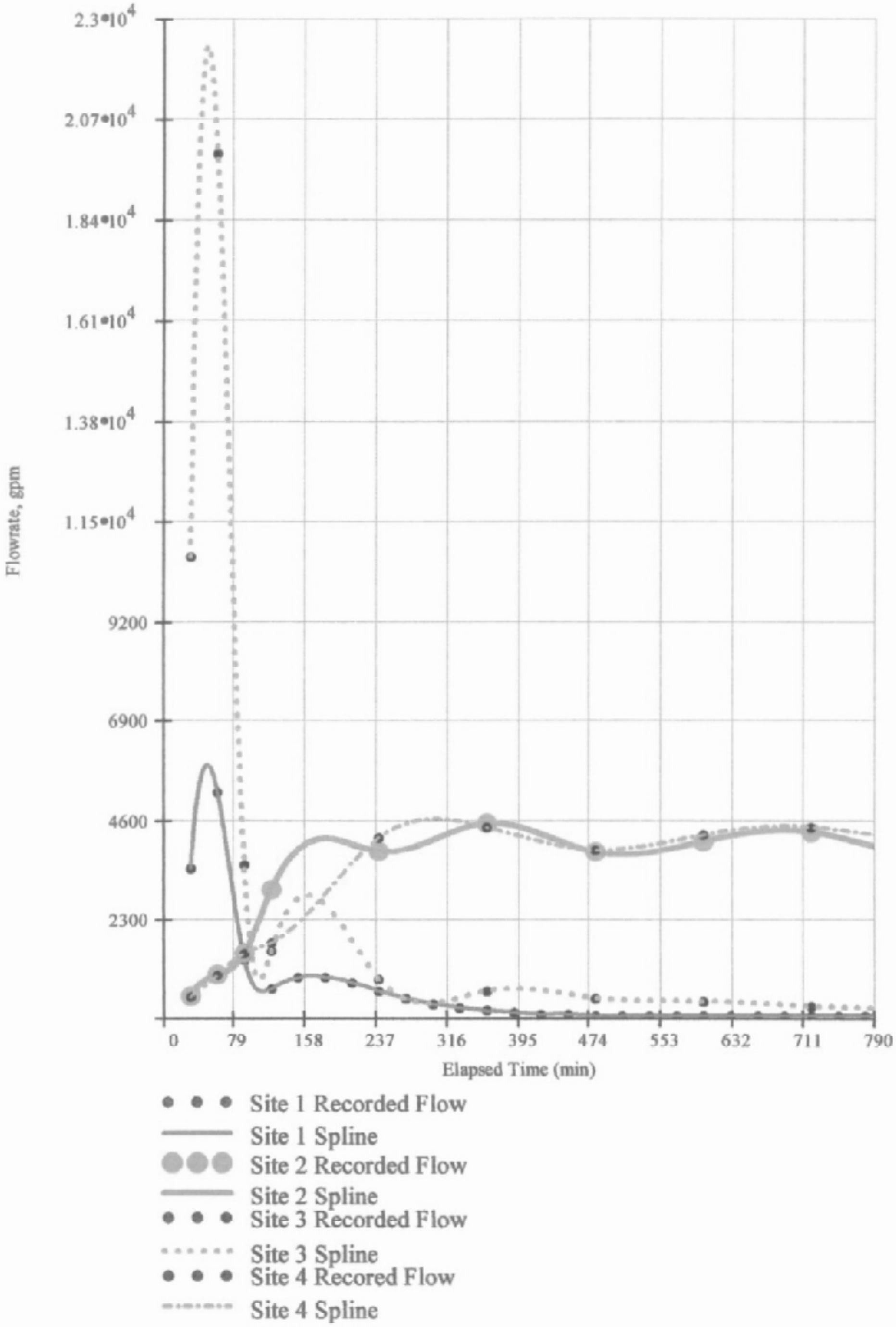


Figure D.1: Flow Comparison for All Sites March 6, 1998

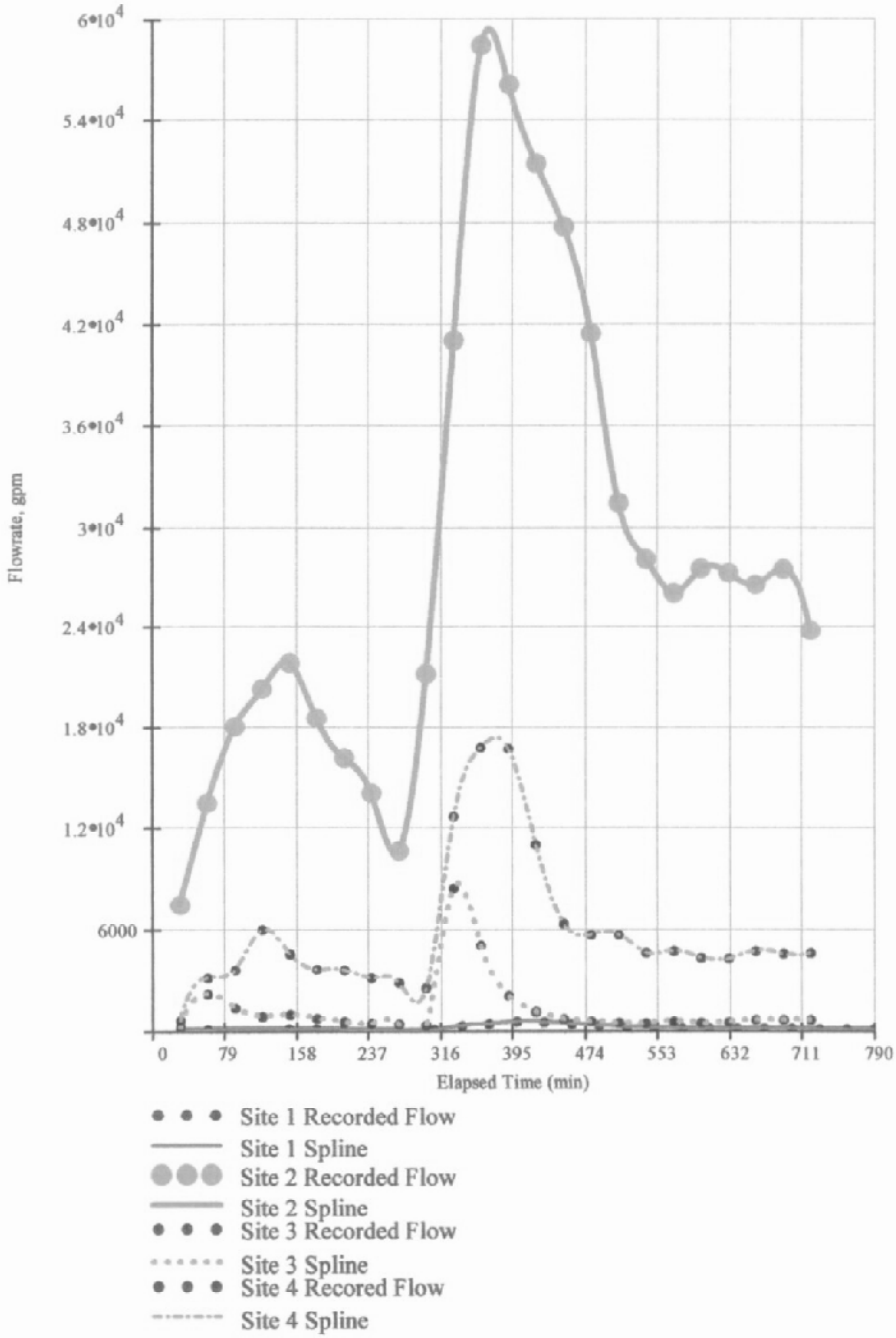


Figure D.2: Flow Comparison for all Sites January 9, 1999

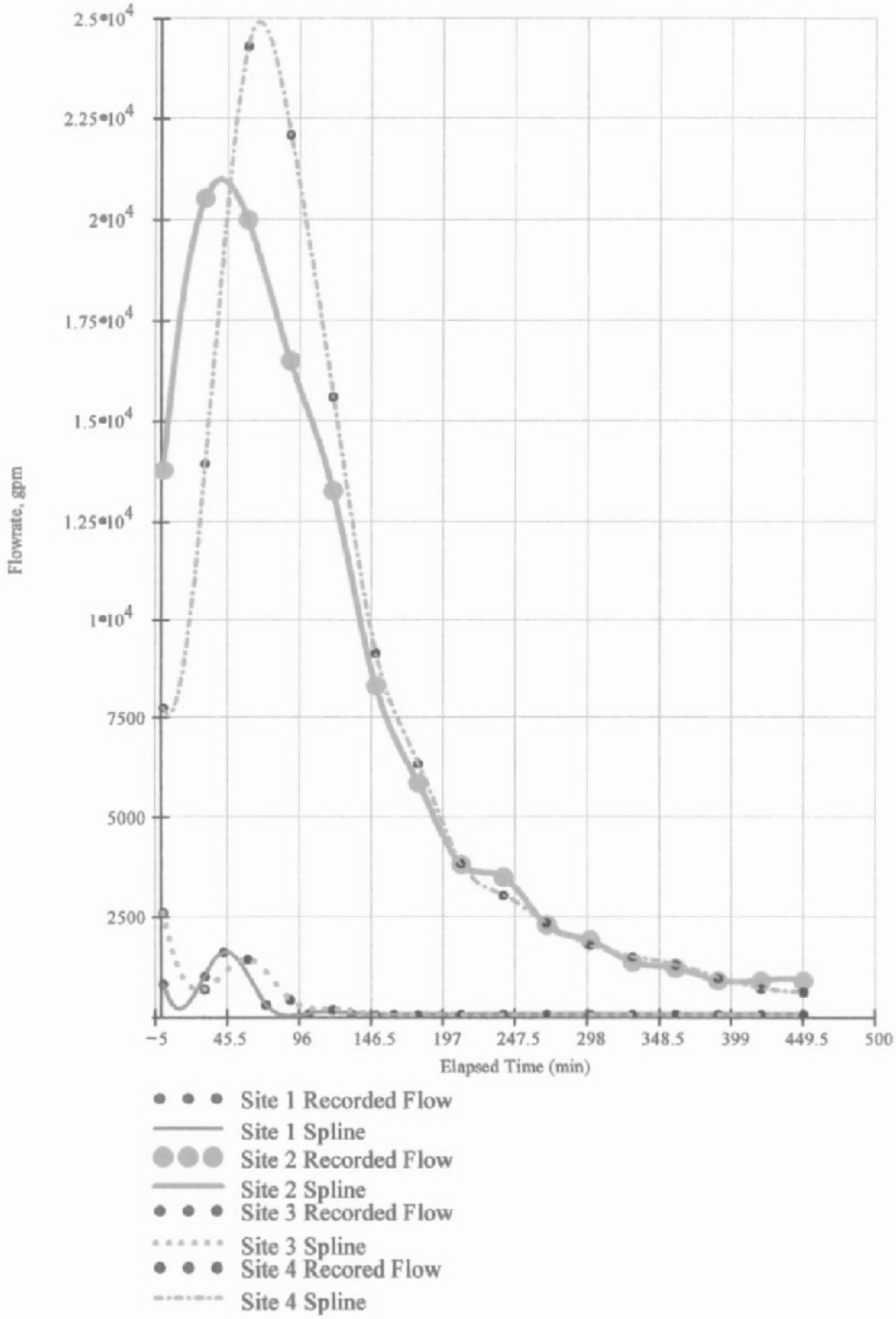


Figure D.3: Flow Comparison for All Sites May 5, 1999

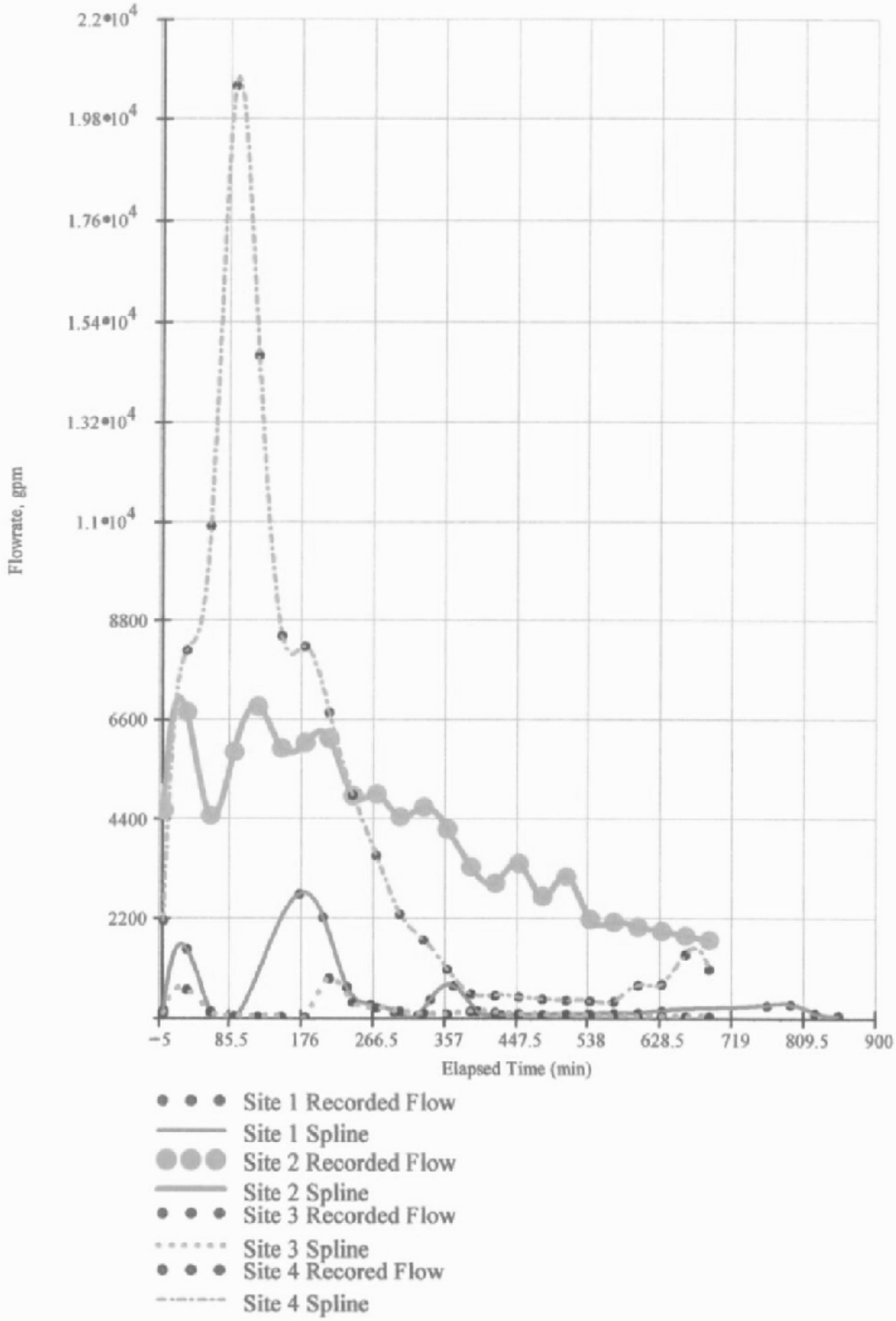


Figure D.4: Flow Comparison for All Sites September 29, 1999

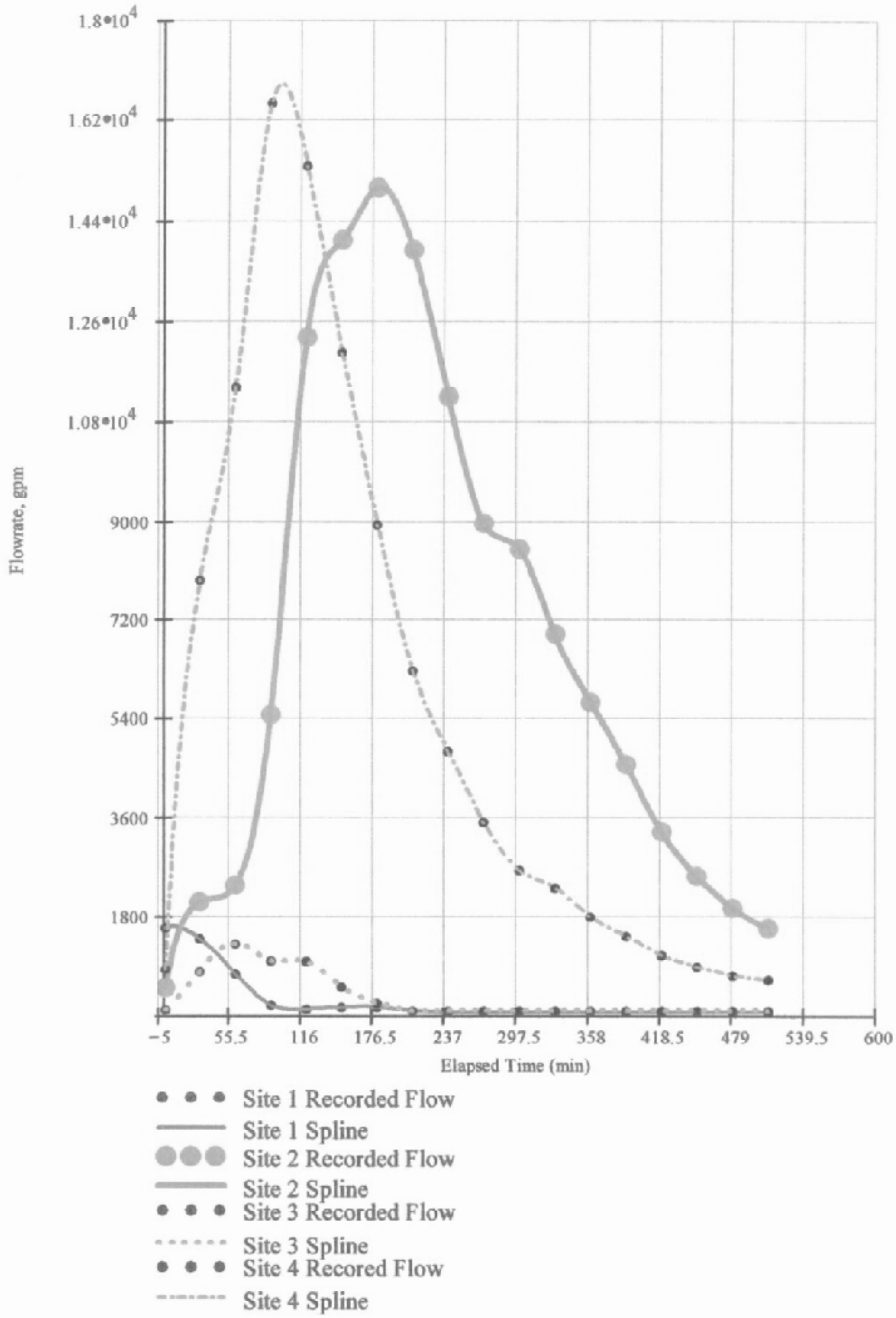


Figure D.5: Flow Comparison for All Sites December 6, 1999

Appendix E
Recorded Flow and Sample Collection

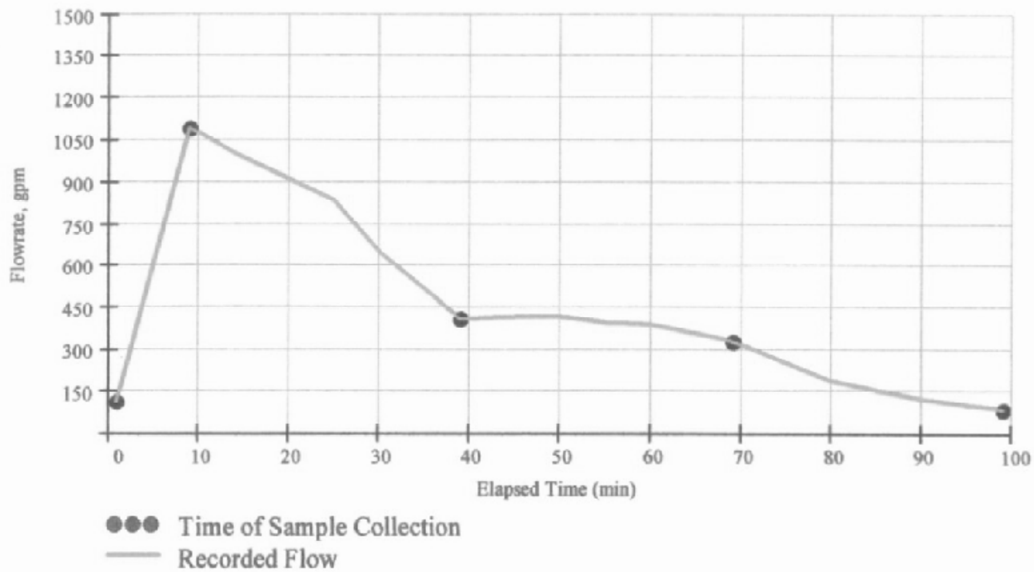


Figure E.1: Site 1 Recorded Flow and Sample Collection March 3, 1999

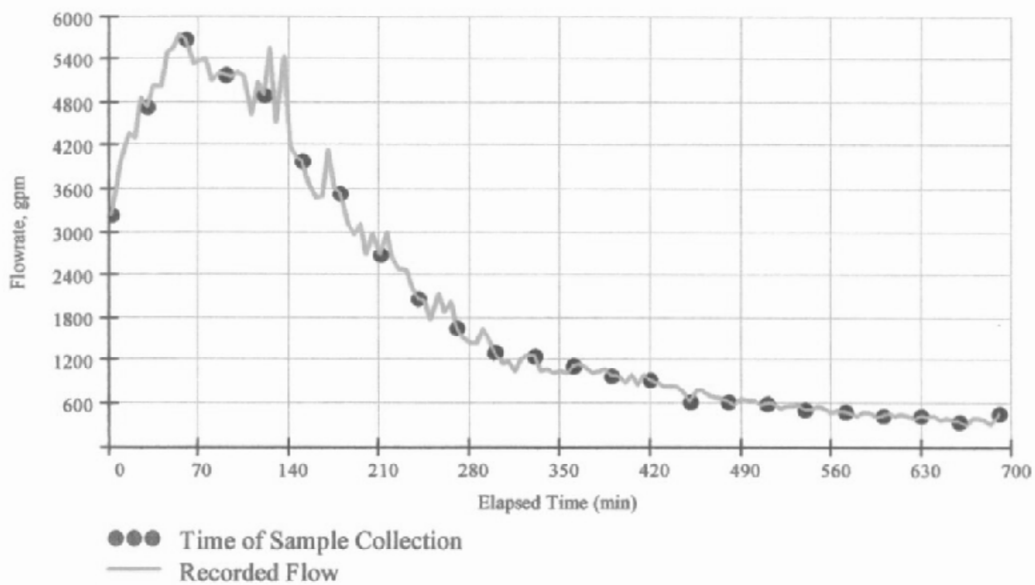


Figure E.2: Site 2 Recorded Flow and Sample Collection March 3, 1999

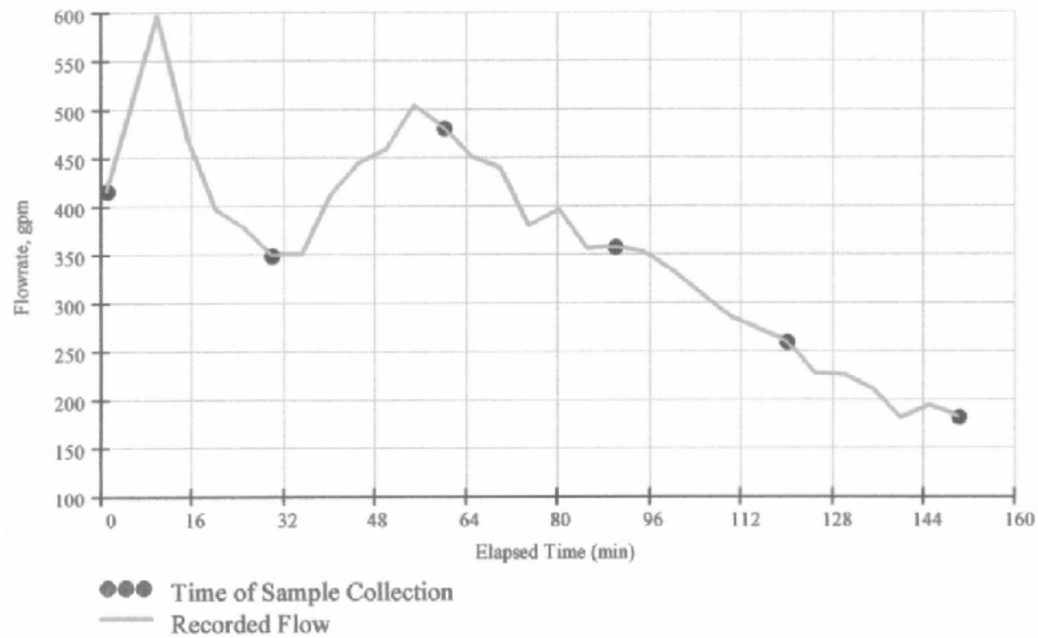


Figure E.3: Site 3 Recorded Flow and Sample Collection March 3, 1999

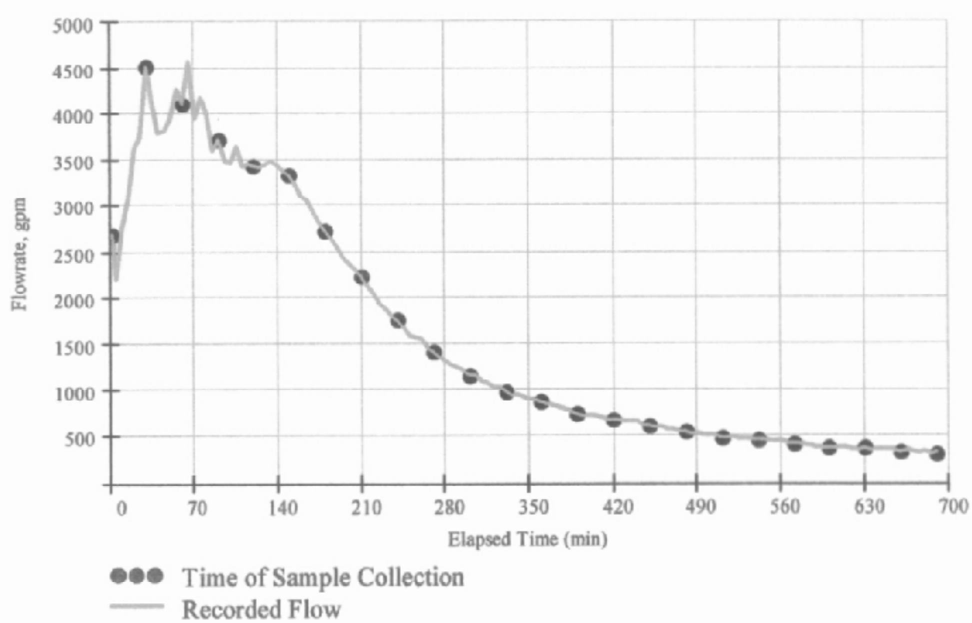


Figure E.4: Site 4 Recorded Flow and Sample Collection March 3, 1999

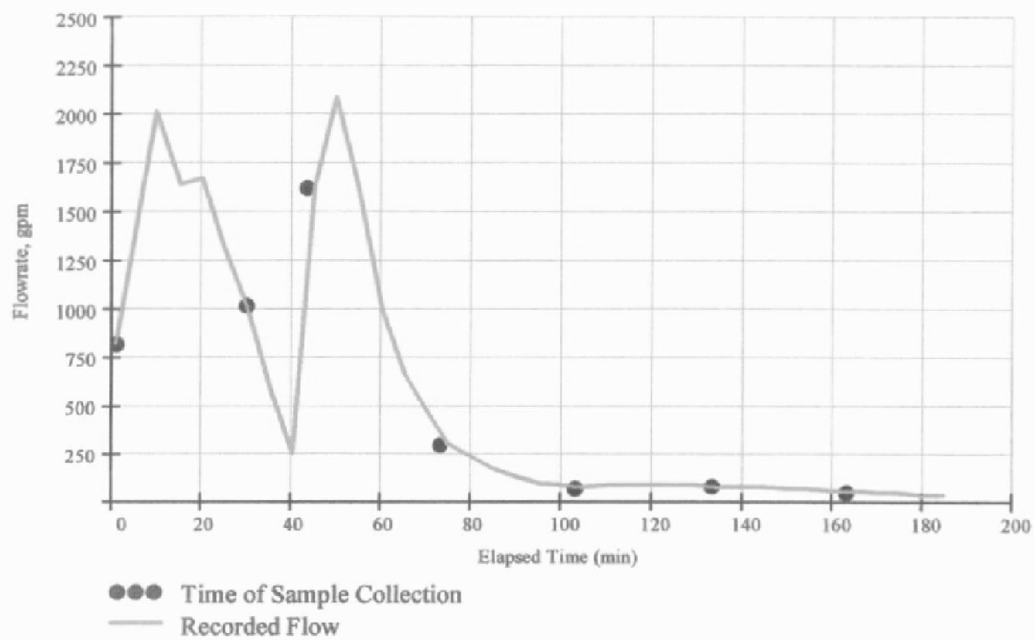


Figure E.5: Site 1 Recorded Flow and Sample Collection May 5, 1999

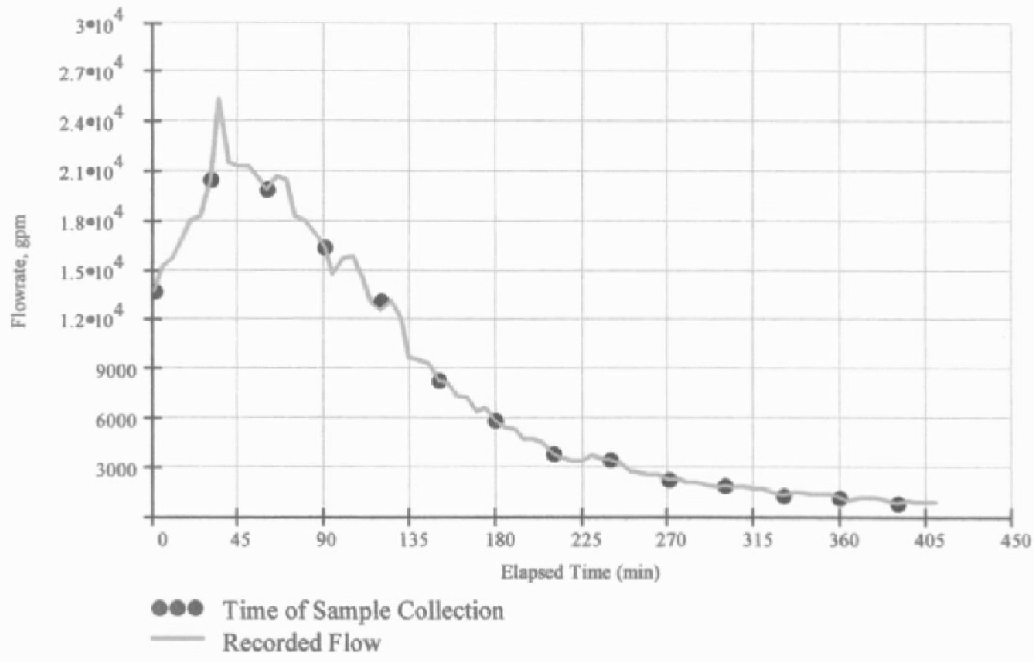


Figure E.6: Site 2 Recorded Flow and Sample Collection May 5, 1999

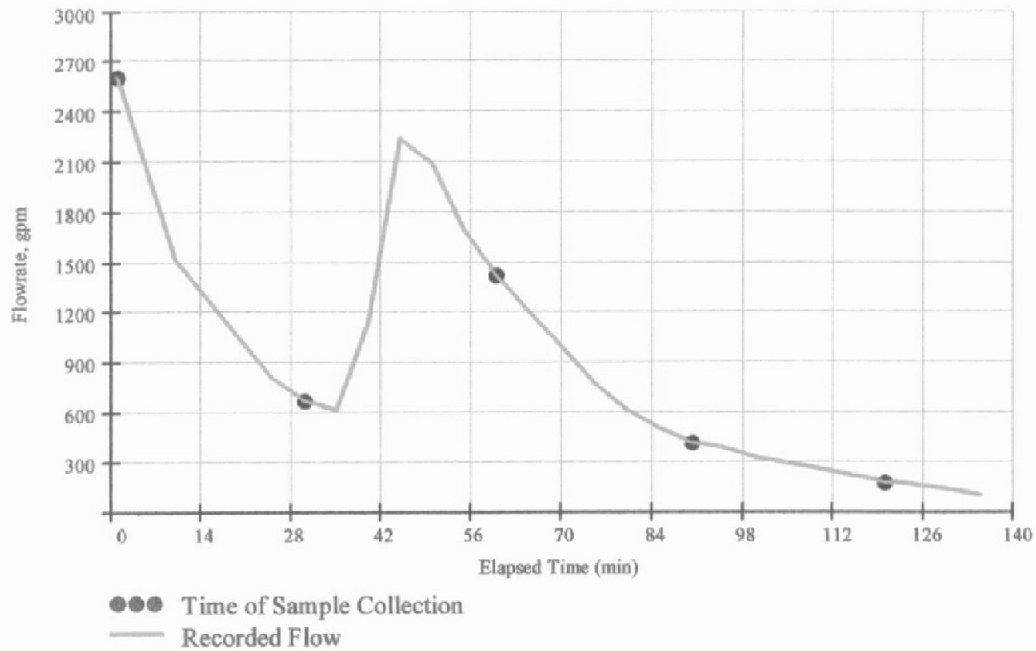


Figure E.7: Site 3 Recorded Flow and Sample Collection May 5, 1999

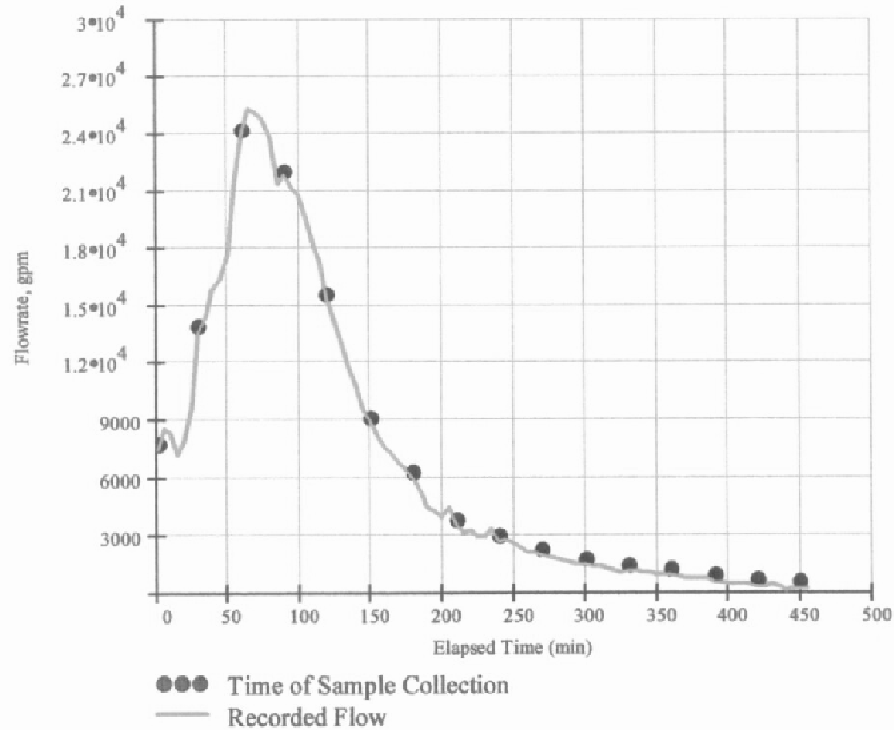


Figure E.8: Site 4 Recorded Flow and Sample Collection May 5, 1999

Appendix F
Pollutant Flux Comparisons for Rain Events
January 9, 1999 and March 3, 1999

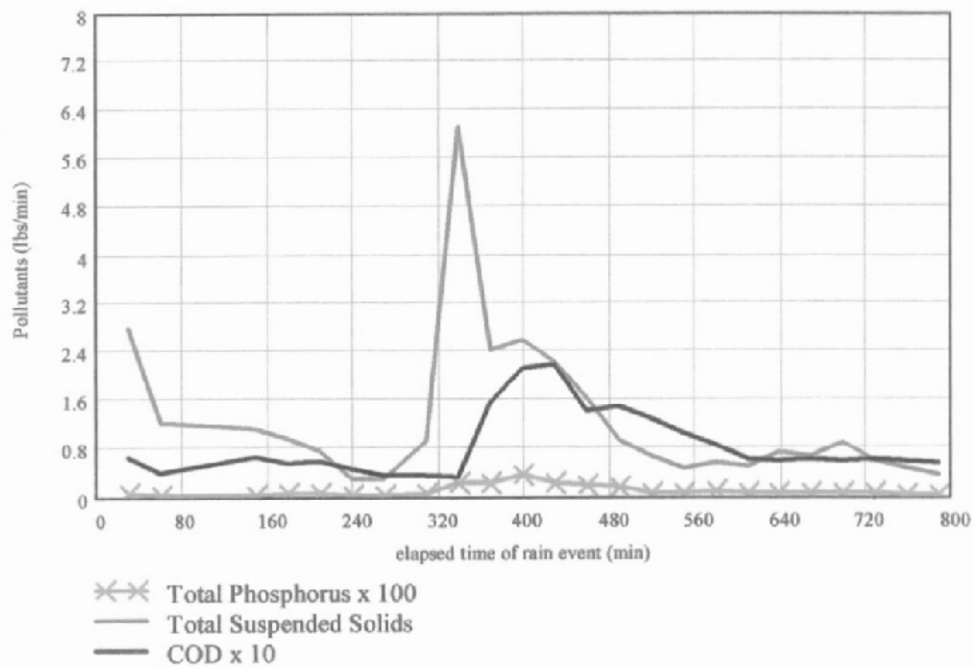


Figure F.1: Pollutant Flux Comparison January 9, 1999 Site 1

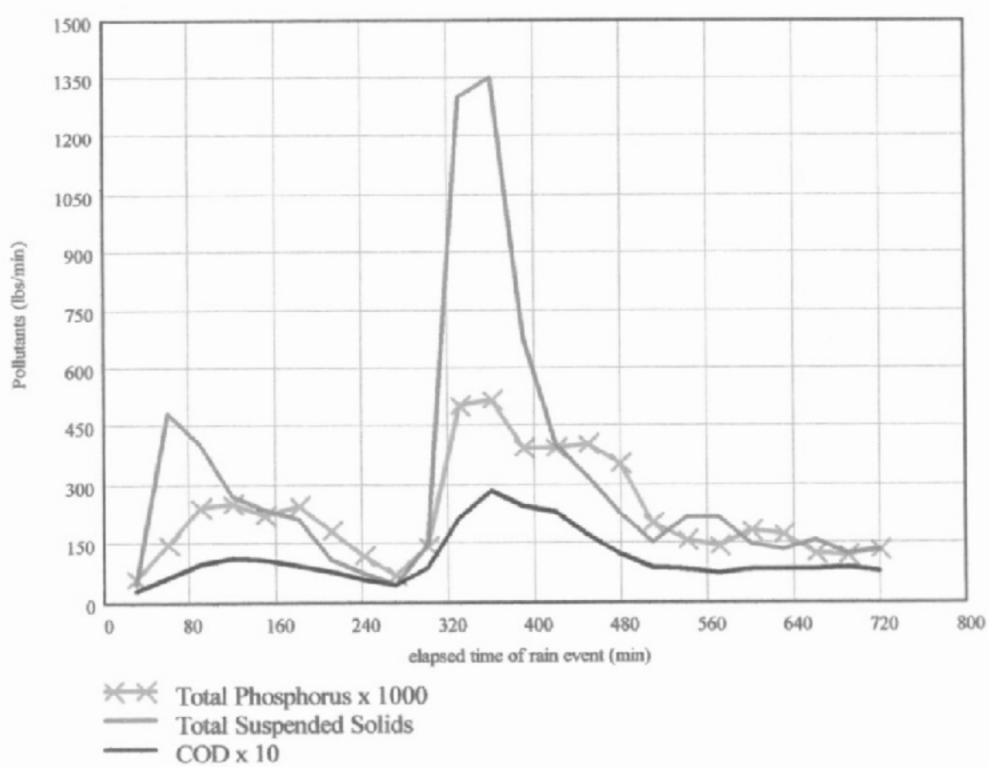


Figure F.2: Pollutant Flux Comparison January 9, 1999 Site 2

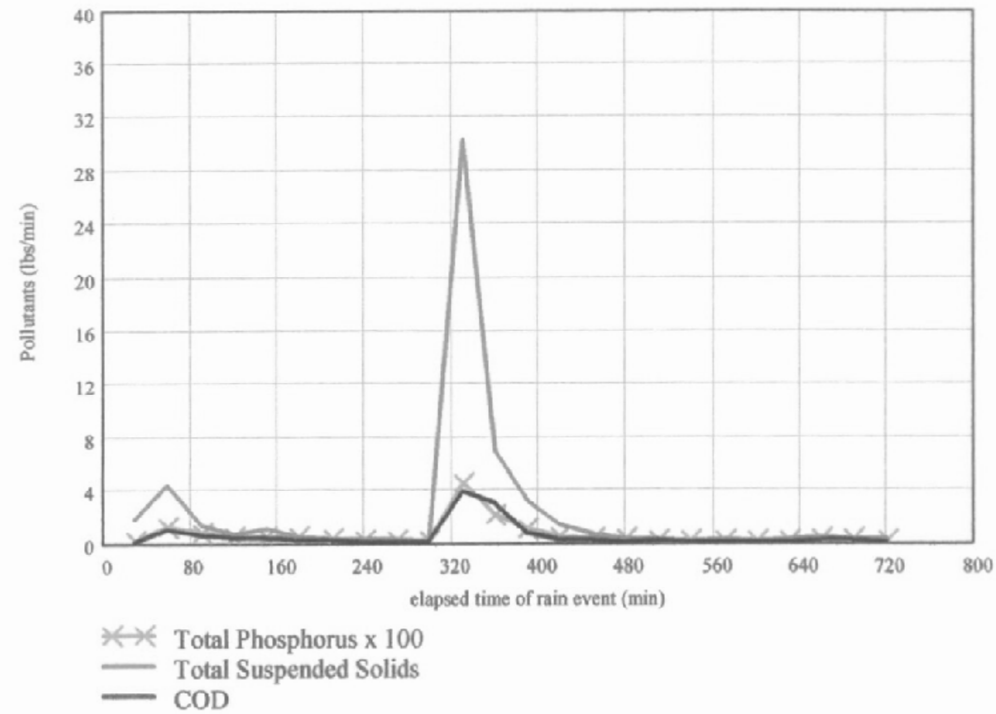


Figure F.3: Pollutant Flux Comparison January 9, 1999 Site 3

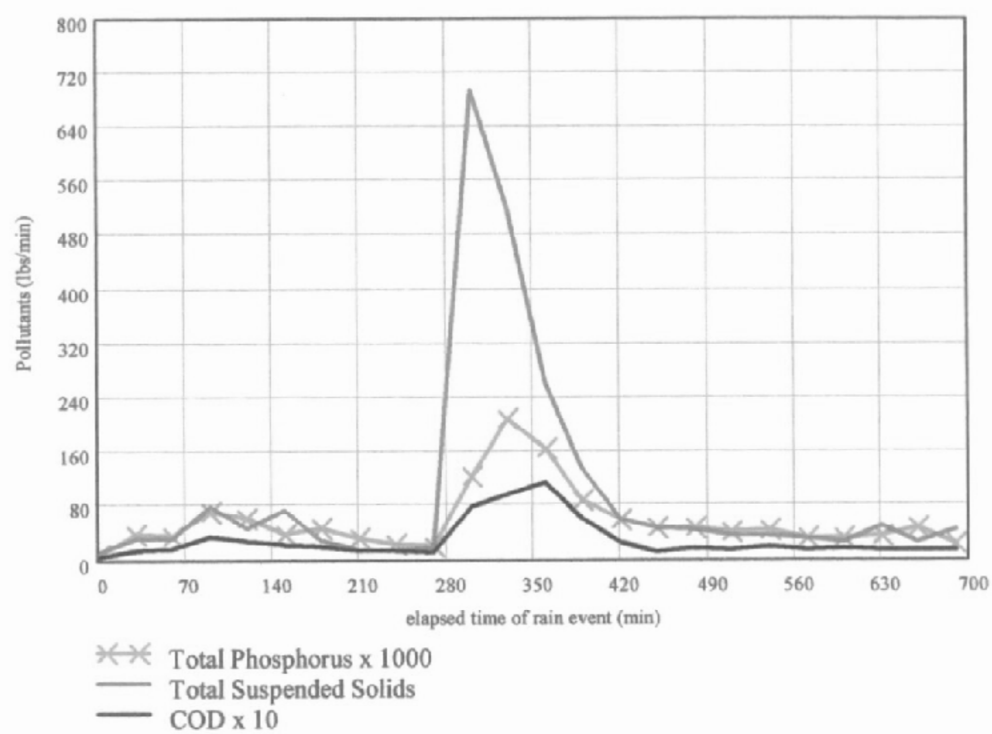


Figure F.4: Pollutant Flux Comparison Site 4 January 9, 1999

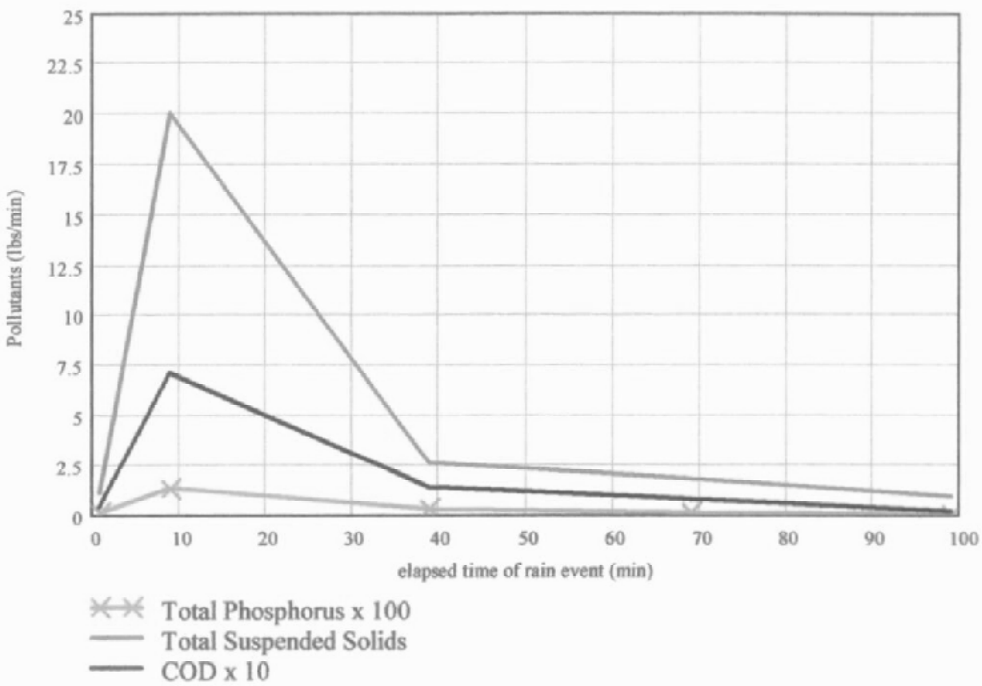


Figure F.5: Pollutant Flux Comparison March 3, 1999 Site 1

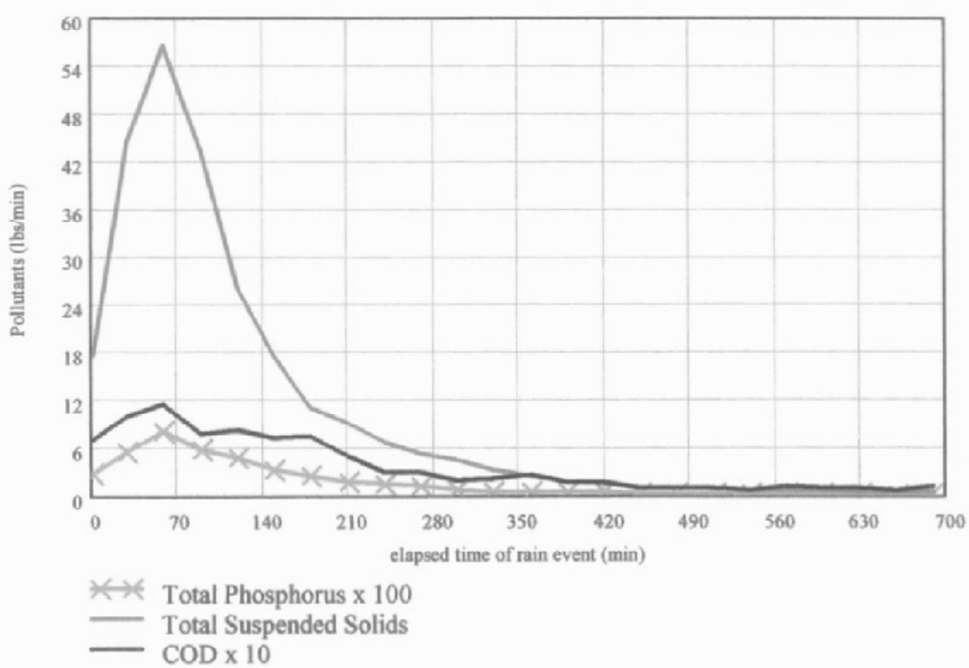


Figure F.6: Pollutant Flux Comparison March 9, 1999 Site 2

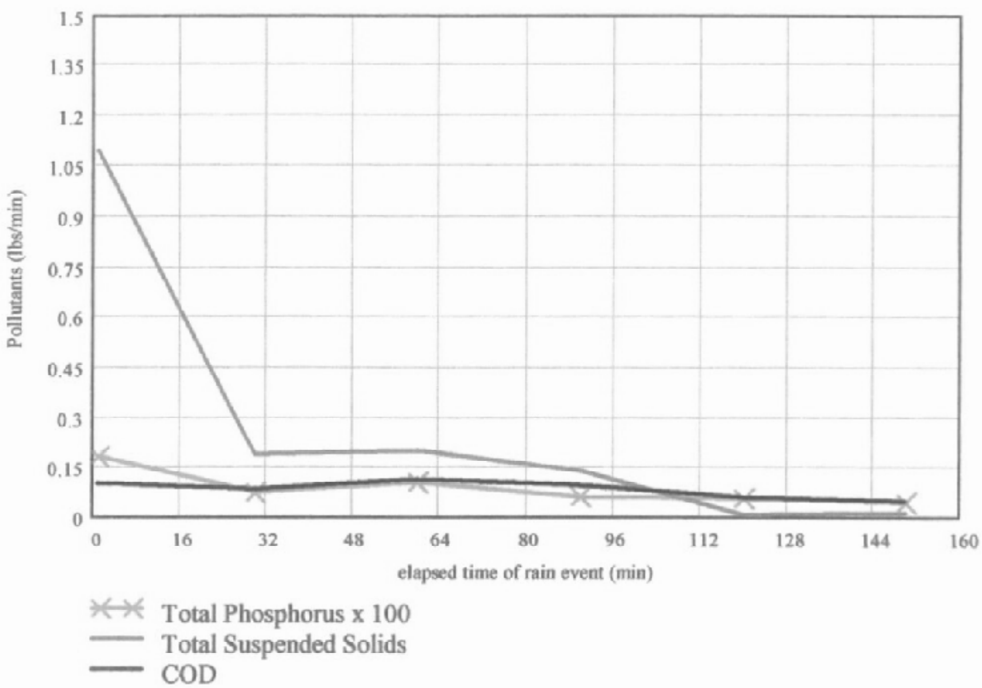


Figure F.7: Pollutant Flux Comparison March 3, 1999 Site 3

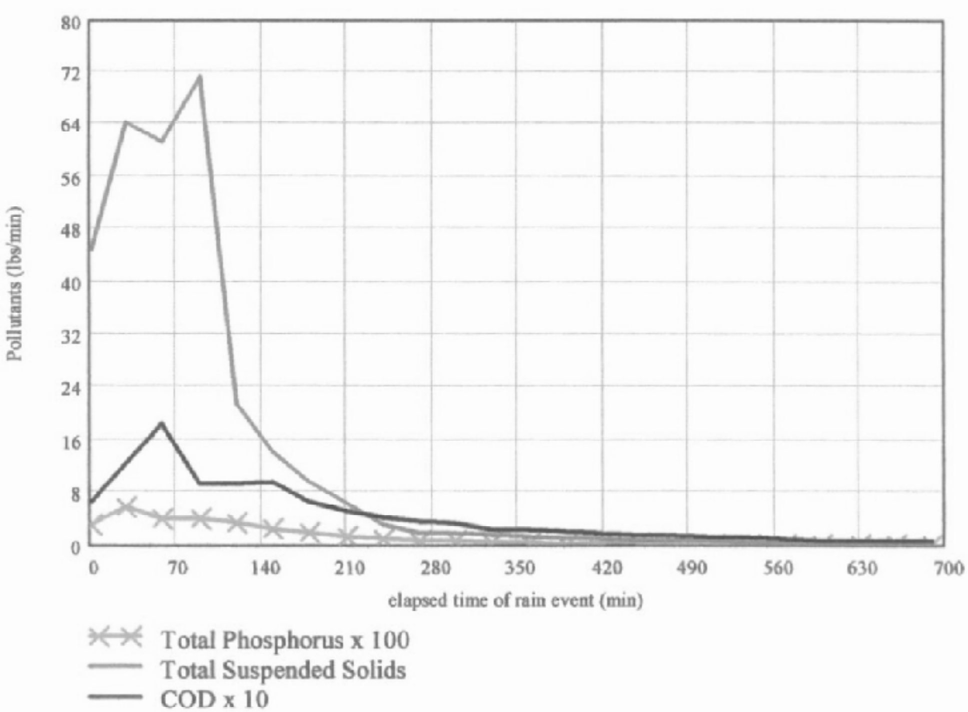


Figure F.8: Pollutant Flux Comparison March 3, 1999 Site 4

Appendix G
Cumulative Load
vs
Cumulative Volume

Example of Data Analysis in Mathcad for Cumulative Load vs. Volume

Flow data are contained in an ascii file called "1_1010999_TP_TSS_COD_FLOW" with the extension ".prn". Mathcad command to read that file into the worksheet is:

DATA :=READPRN("1_010999_TP_TSS_COD_FLOW.prn")

File name definition:

The first number is the site from which the sample came,
The next set of six numbers are the date of sample collection,
The analytes tested for discrete analysis,
Flow,
File command.

DATA =

1.12	$5.232 \cdot 10^3$	122	64	30
0.68	$1.684 \cdot 10^3$	55	88	60
0.29	$1.387 \cdot 10^3$	80	98	149
0.79	$1.16 \cdot 10^3$	68	101	179
0.8	$1.02 \cdot 10^3$	80	89	209
0.6	527	82	66	239
0.97	690	81	52	269
0.99	$1.8 \cdot 10^3$	74	62	309
0.88	$2.43 \cdot 10^3$	13	302	339
0.65	717	46	407	369
0.82	587	48	531	399
0.57	520	51	514	429

* Note Mathcad shows 11 of the total number of rows of the above matrix at a time to conserve on space.

$i := 0 .. 23$ number of data/rows in the matrix

Column 0 = Total Phosphorus
Column 1 = TSS
Column 2 = COD
Column 3 = Flow
Column 4 = Elapsed Time
Column 5 = Real Time-day.decimal day

DATA is divided up into six individual vectors. Each column is identified as to the contents.

Total Phosphorus: is the concentration from each discrete sample collected
Total Suspended Solids: is the concentration from each discrete sample collected
COD: is the concentration from each discrete sample collected
Flow: is the gallons per minute reading taken at sample collection time

Elapsed Time: represents the clock time that the sample was collected

Real Time-day: day and time the sample was collected in decimal day e.g. 12 noon is 0.5 decimal day

"elasped time" or "runoff time" represents the fourth column of the matrix. It contains the interval of time between sample collection.

$$runoff\_time_i := DATA_{i,4} \cdot min$$

"Q" represents the third column of the matrix, which is flowrate at time of sample collection in gallons per minute.

$$Q_i := DATA_{i,3} \cdot \frac{gal}{min}$$

Examples of flowrate and runoff time:

$$Q = \begin{pmatrix} 64 \\ 88 \\ 98 \\ 101 \\ 89 \\ 66 \\ 52 \\ 62 \\ 302 \\ 407 \\ 531 \\ 514 \\ 415 \\ 313 \\ 235 \end{pmatrix} \cdot \frac{gal}{min} \qquad runoff\_time = \begin{pmatrix} 30 \\ 60 \\ 149 \\ 179 \\ 209 \\ 239 \\ 269 \\ 309 \\ 339 \\ 369 \\ 399 \\ 429 \\ 459 \\ 489 \\ 519 \end{pmatrix} \cdot min$$

The volume of runoff that entered the basin is the area under the hydrograph approximated by the splined curve through all individual flow measurements.

Limits of integration are the elapsed time from start to the end of runoff induced flow:

$$TIME := 30\cdot min, 31\cdot min .. 789\cdot min$$

$$Tvolume := \int_{30\cdot min}^{789\cdot min} (interp(cspline(runoff\_time, Q), runoff\_time, Q, TIME))\, dTIME$$

The total runoff volume that entered the basin is: $Tvolume = 140595 \cdot gal$

Integrated volume of runoff is from the start of the runoff to time t.

$$t := 30, 31 .. 789$$

$$\text{volume}_t := \int_{30\cdot min}^{t\cdot min} (\text{interp}(\text{cspline}(\text{runoff\_time}, Q), \text{runoff\_time}, Q, \text{TIME}))\, d\text{TIME}$$

Cumulative volume is the integrated volume divided by the total volume

Cumulative loads are calculated using pollutant flux. First the flux is integrated from time t and then divided by total flux.

Total Phosphorus-discrete sample from column zero in matrix

$$TP_i := DATA_{i,0} \cdot \frac{mg}{liter}$$

Total Suspended Solids-discrete sample from column 1 in matrix

$$TSS_i := DATA_{i,1} \cdot \frac{mg}{liter}$$

COD-discrete sample from column 2 in matrix

$$COD_i := DATA_{i,2} \cdot \frac{mg}{liter}$$

TP = (mg/liter)

1.12
0.68
0.29
0.79
0.8
0.6
0.97
0.99
0.88
0.65
0.82
0.57
0.61
0.62
0.26

TSS = (mg/liter)

$5.232 \cdot 10^3$
$1.684 \cdot 10^3$
$1.387 \cdot 10^3$
$1.16 \cdot 10^3$
$1.02 \cdot 10^3$
527
690
$1.8 \cdot 10^3$
$2.43 \cdot 10^3$
717
587
520
473

COD = (mg/liter)

122
55
80
68
80
82
81
74
13
46
48
51
41
57
66

Pollutant flux is flow x concentration. This shows pounds of pollutants discharged per minute over the hydrograph.

$TPFlux_i := TP_i \cdot Q_i$ $\quad TSSFlux_i := TSS_i \cdot Q_i$ $\quad CODFlux_i := COD_i \cdot Q_i$

$$TPFlux = \begin{pmatrix} 5.982\cdot10^{-4} \\ 4.994\cdot10^{-4} \\ 2.372\cdot10^{-4} \\ 6.659\cdot10^{-4} \\ 5.942\cdot10^{-4} \\ 3.305\cdot10^{-4} \\ 4.209\cdot10^{-4} \\ 5.122\cdot10^{-4} \\ 2.218\cdot10^{-3} \\ 2.208\cdot10^{-3} \\ 3.634\cdot10^{-3} \end{pmatrix} \frac{lb}{min} \quad TSSFlux = \begin{pmatrix} 2.794 \\ 1.237 \\ 1.134 \\ 0.978 \\ 0.758 \\ 0.29 \\ 0.299 \\ 0.931 \\ 6.124 \\ 2.435 \\ 2.601 \\ 2.231 \\ 1.638 \\ 0.94 \\ 0.653 \end{pmatrix} \frac{lb}{min} \quad CODFlux = \begin{pmatrix} 0.065 \\ 0.04 \\ 0.065 \\ 0.057 \\ 0.059 \\ 0.045 \\ 0.035 \\ 0.038 \\ 0.033 \\ 0.156 \\ 0.213 \\ 0.219 \\ 0.142 \\ 0.149 \\ 0.129 \end{pmatrix} \frac{lb}{min}$$

Total pollutant mass loading rate is the concentration times the corresponding flowrate at which the samples were collected. The mass load is the area under the mass load vs. runoff time splined curve:

Length of event in minutes: $\quad TIME := 30\cdot min, 31\cdot min .. 789\cdot min$

$$TP\_LoadT := \int_{30\cdot min}^{789\cdot min} (interp(cspline(runoff\_time, TPFlux), runoff\_time, TPFlux, TIME))\,dTIME$$

$$TSS\_LoadT := \int_{30\cdot min}^{789\cdot min} (interp(cspline(runoff\_time, TSSFlux), runoff\_time, TSSFlux, TIME))\,dTIME$$

$$COD\_LoadT := \int_{30 \cdot min}^{789 \cdot min} (interp(cspline(runoff\_time, CODFlux), runoff\_time, CODFlux, TIME))\, dTIM$$

The total mass load entering the basin during the rain event for total phosphorus, total suspended solids, and COD are:

$$TP\_LoadT = 0.724 \cdot lb$$

$$TSS\_LoadT = 906.109 \cdot lb$$

$$COD\_LoadT = 63.379 \cdot lb$$

The integrated mass loading rate is calculated from the beginning of the runoff to time t

$$TP\_Load_t := \int_{30 \cdot min}^{t \cdot min} (interp(cspline(runoff\_time, TPFlux), runoff\_time, TPFlux, TIME))\, dTIME$$

$$TSS\_Load_t := \int_{30 \cdot min}^{t \cdot min} (interp(cspline(runoff\_time, TSSFlux), runoff\_time, TSSFlux, TIME))\, dTIME$$

$$COD\_Load_t := \int_{30 \cdot min}^{t \cdot min} (interp(cspline(runoff\_time, CODFlux), runoff\_time, CODFlux, TIME))\, dTIME$$

Example of cumulative load versus cumulative volume

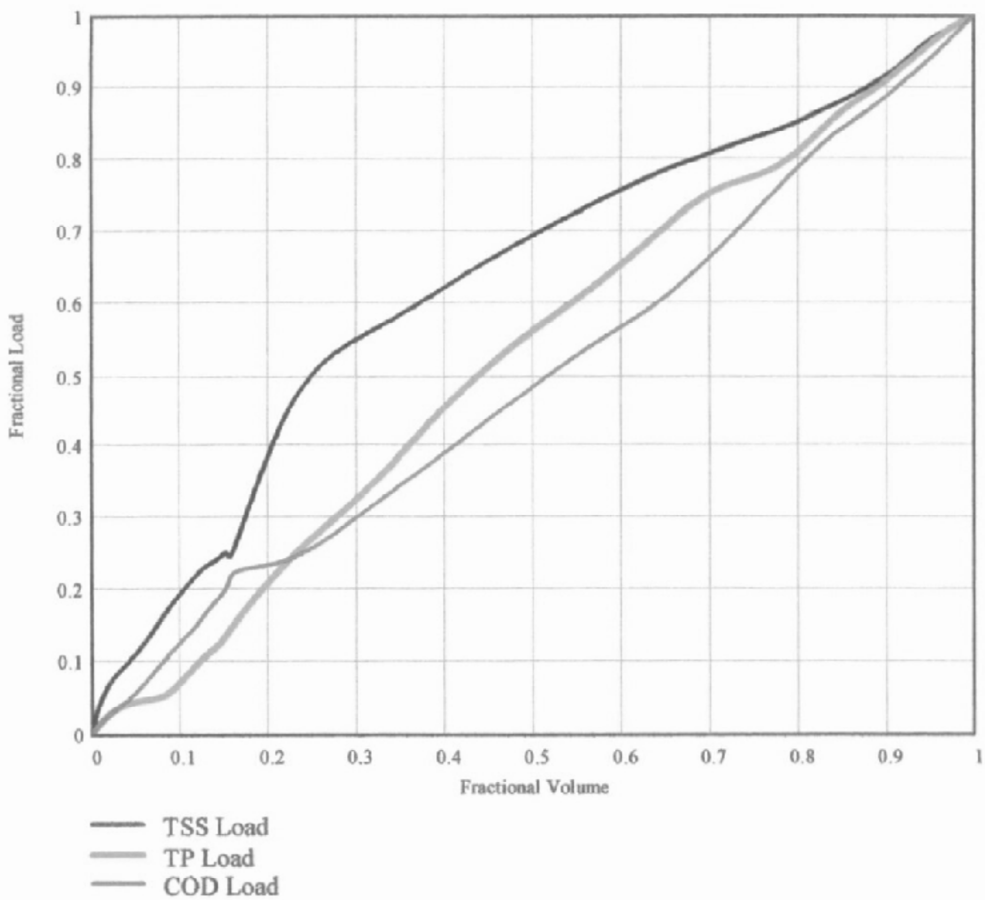


Figure G.1: Cumulative Load vs. Volume January 9, 1999 Site 1

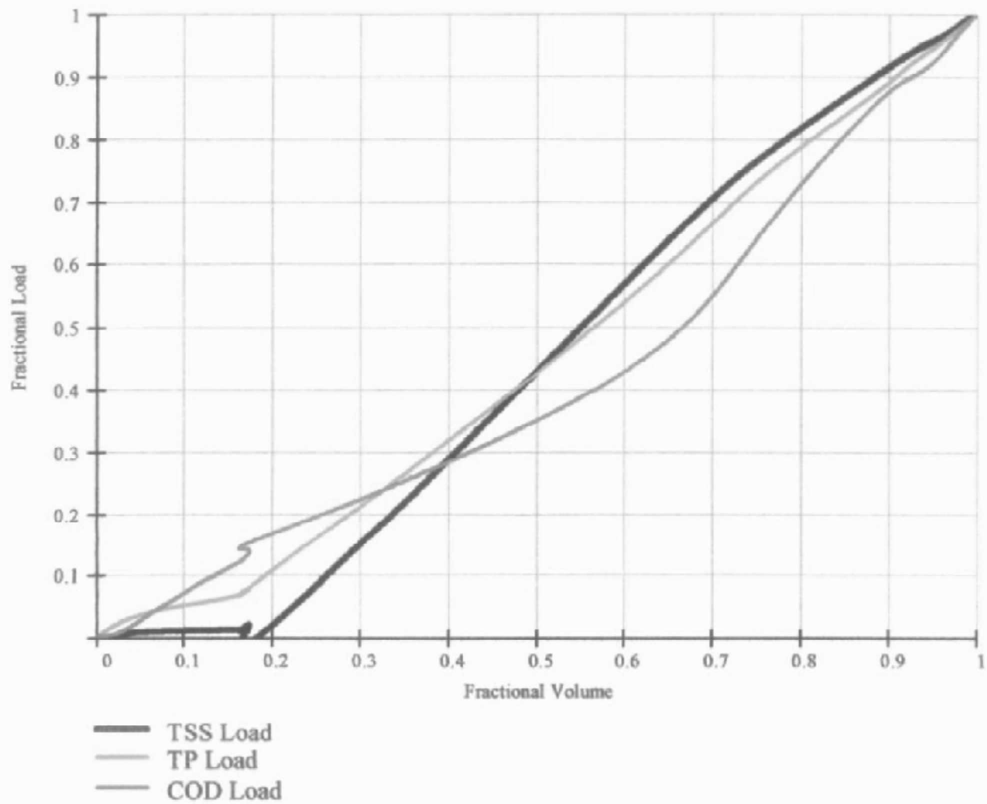


Figure G.2: Cumulative Load vs. Volume March 6, 1998 Site 2

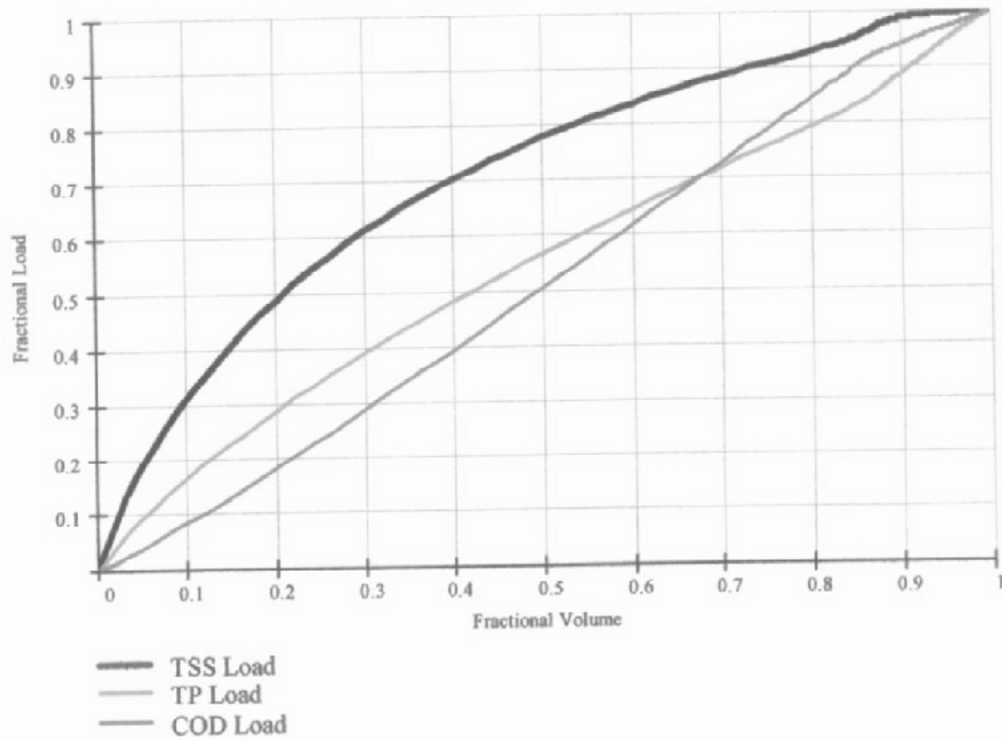


Figure G.3: Cumulative Load vs. Volume March 6, 1998 Site 3

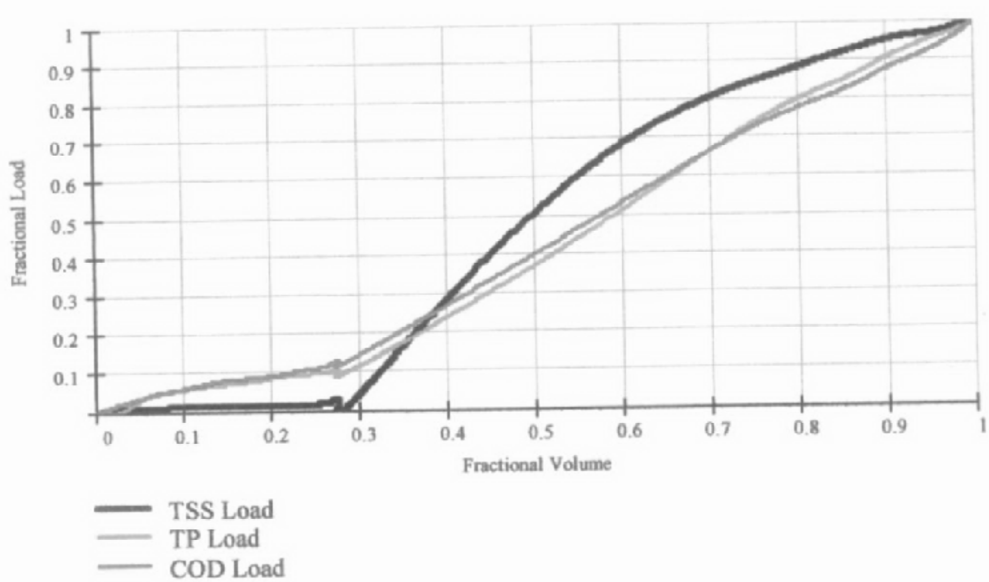


Figure G.4: Cumulative Load vs. Volume March 6, 1998 Site 4

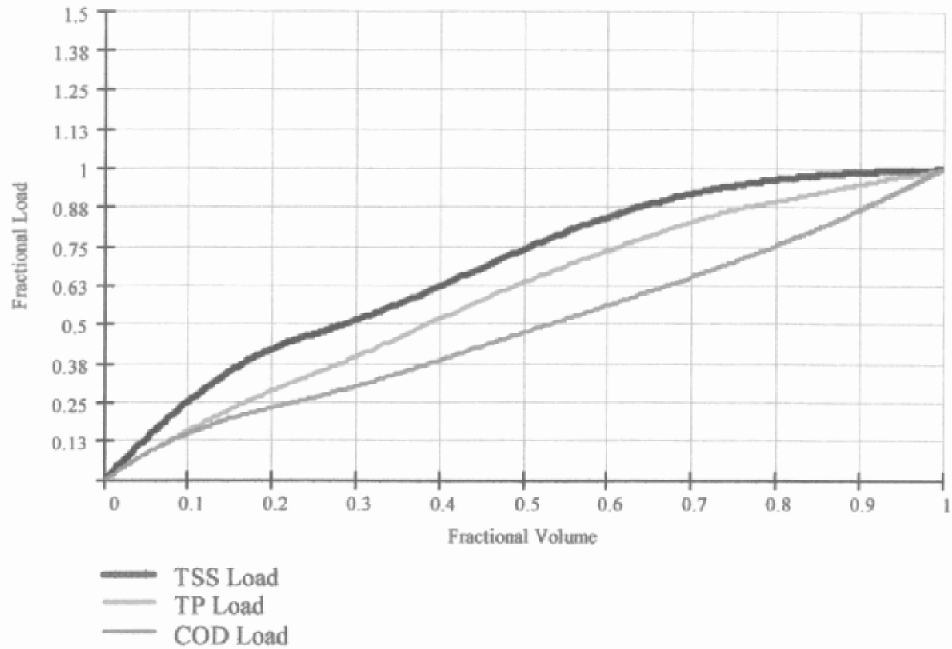


Figure G.5: Cumulative Load vs.Volume March 17, 1998 Site 1

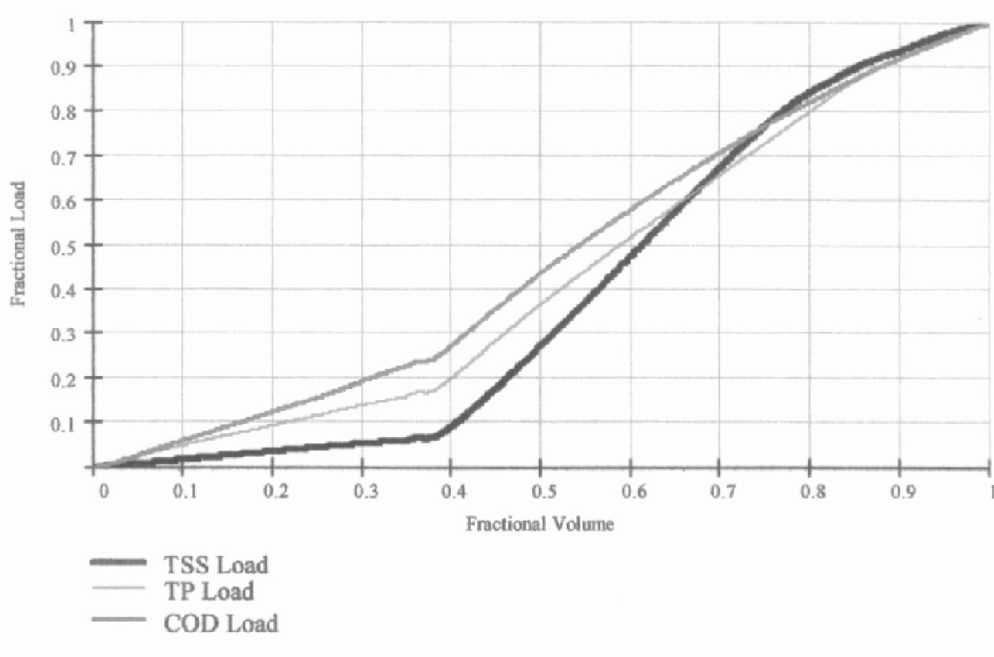


Figure G.6: Cumulative Load vs.Volume March 17,1998 Site 2

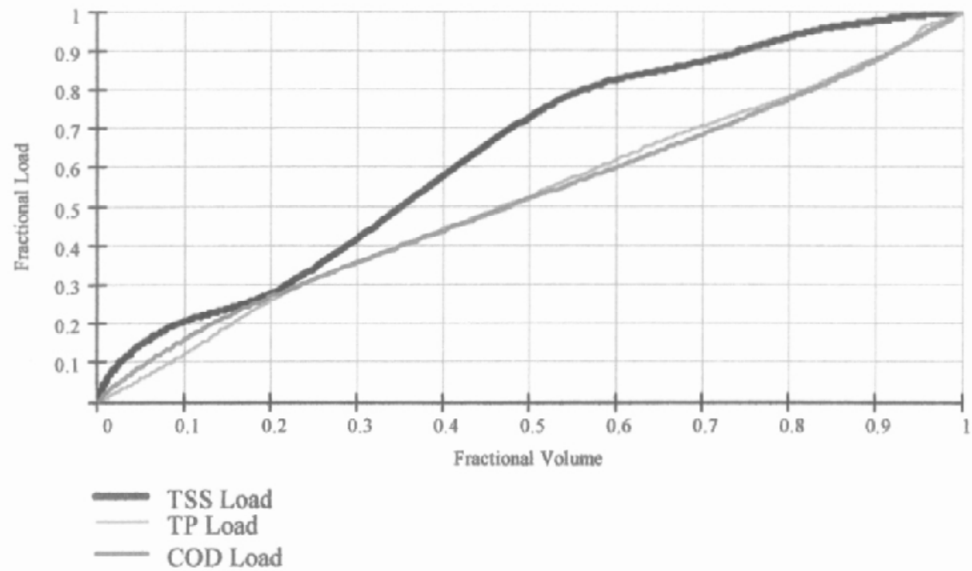


Figure G.7: Cumulative Load vs.Volume March 17, 1998 Site 3

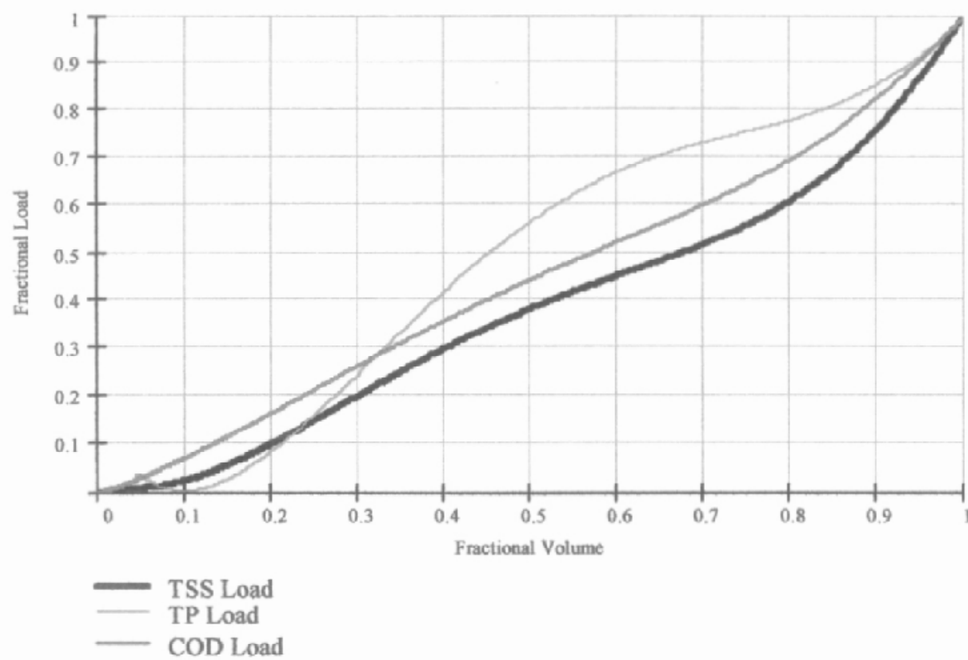


Figure G.8: Cumulative Load vs. Volume March 17, 1998 Site 4

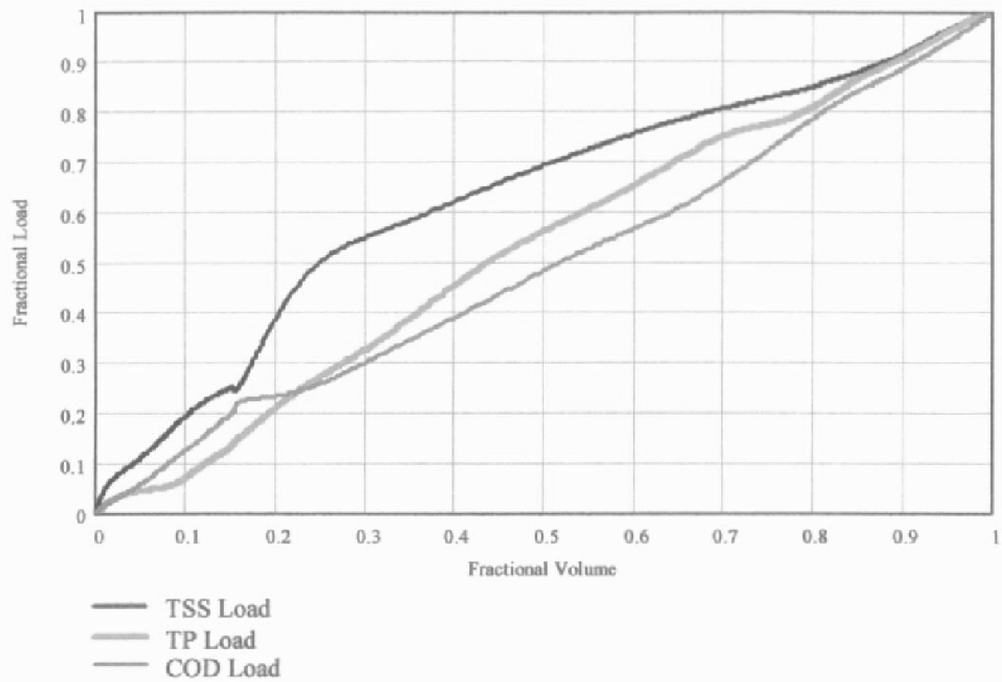


Figure G.9: Cumulative Load vs. Volume January 9, 1999 Site 1

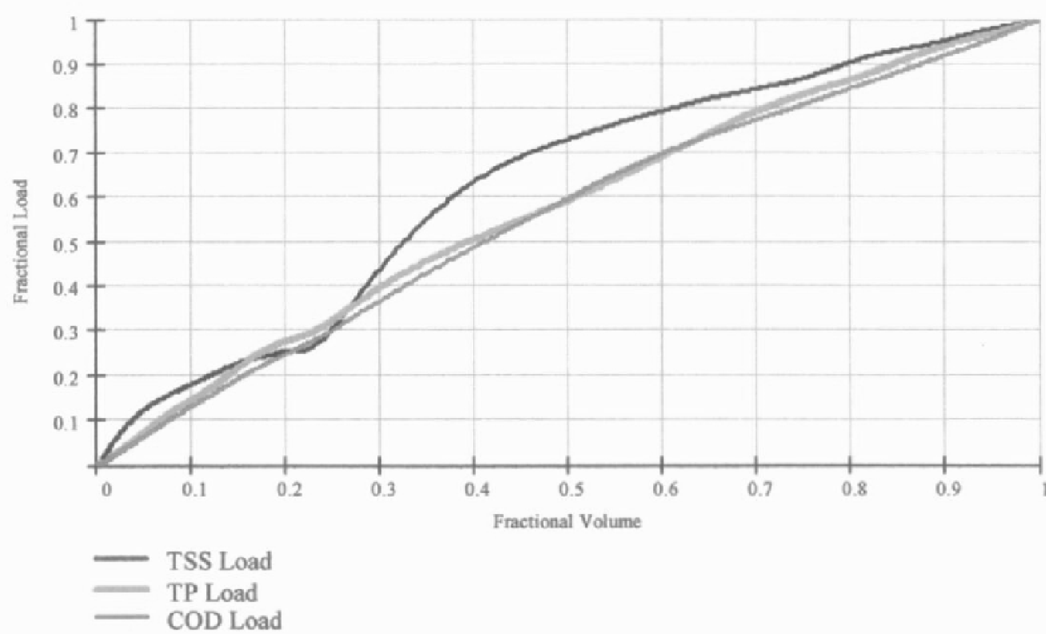


Figure G.10: Cumulative Load vs. Volume January 9, 1999 Site 2

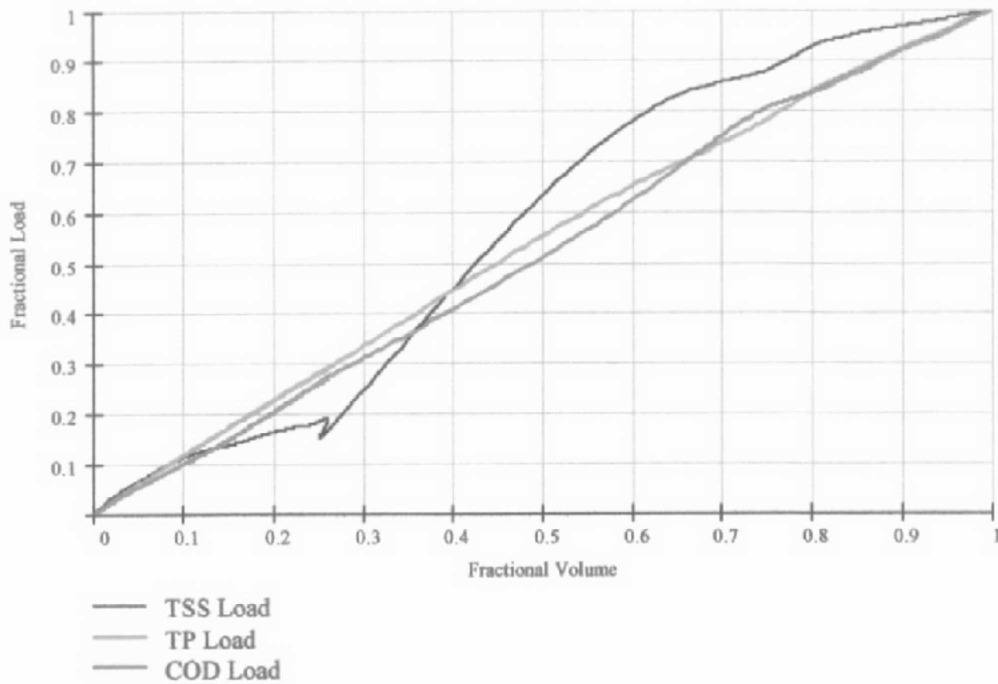


Figure G.11: Cumulative Load vs. Volume January 9, 1999 Site 3

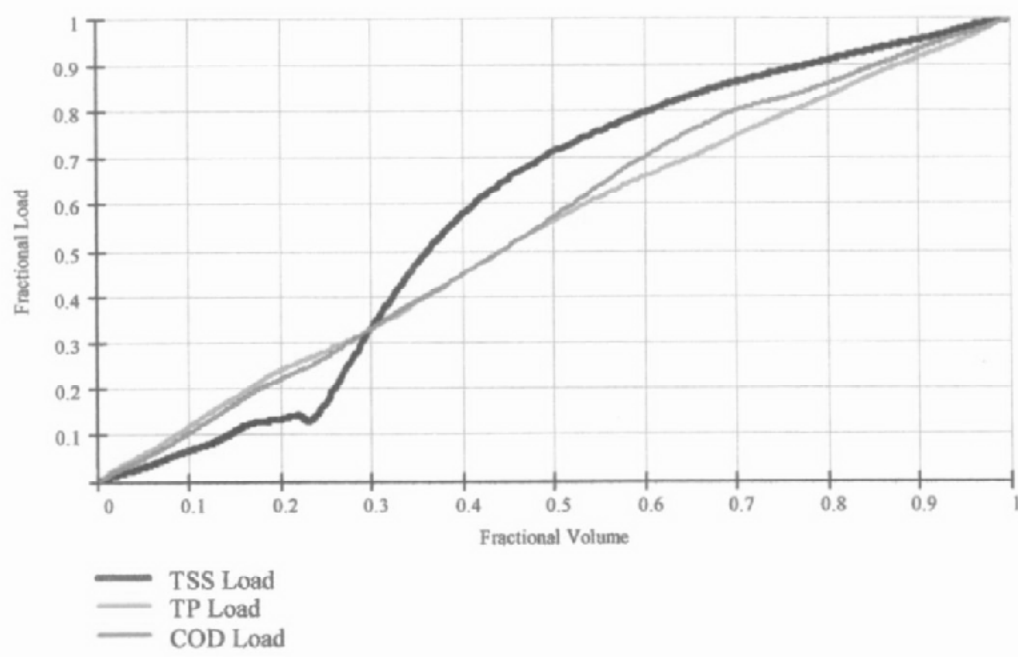


Figure G.12: Cumulative load versus cumulative volume Site 4 January 9, 1999

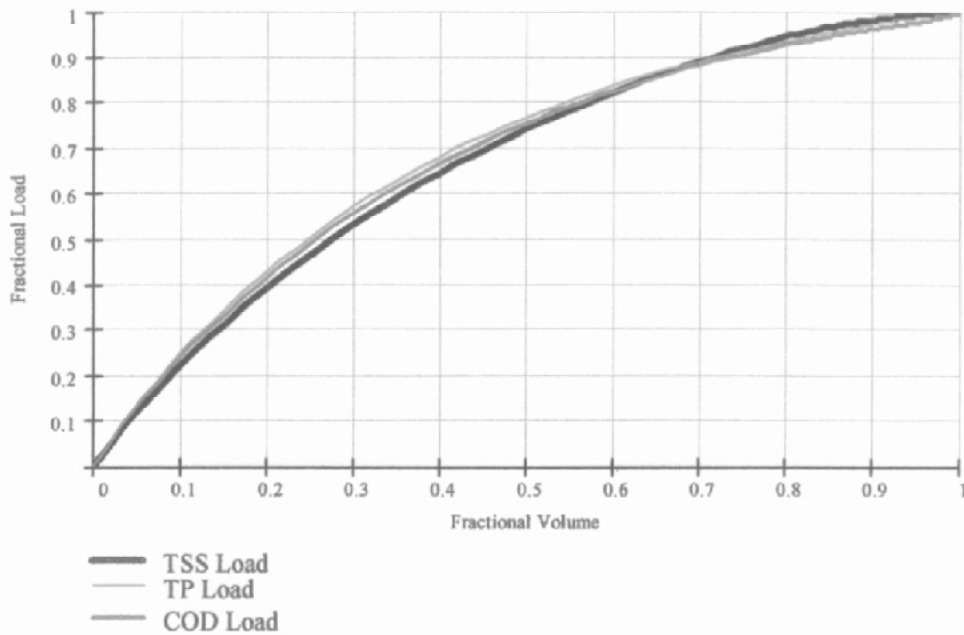


Figure G.13: Cumulative Load vs. Volume March 25, 1999 Site 1

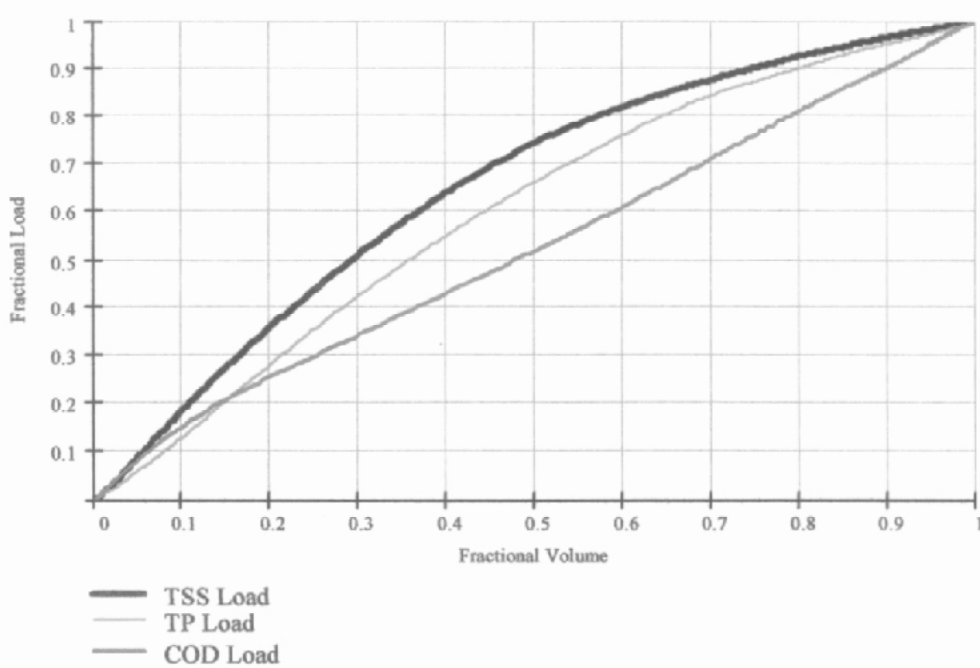


Figure G.14: Cumulative Load vs. Volume March 25, 1999 Site 2

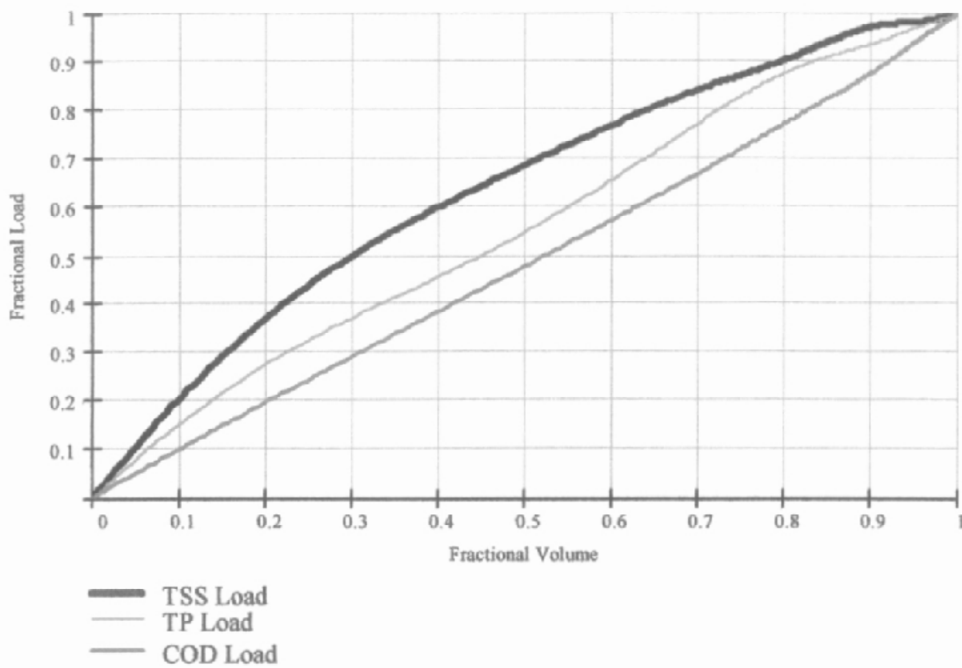


Figure G.15: Cumulative Load vs. Volume March 25, 1999 Site 3

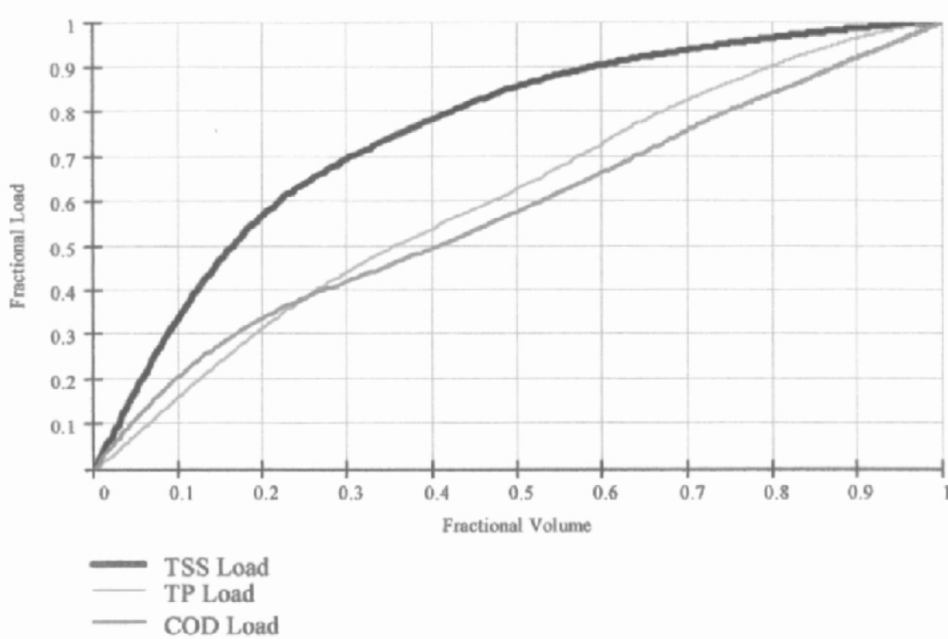


Figure G.16: Cumulative Load vs. Volume March 25, 1999 Site 4

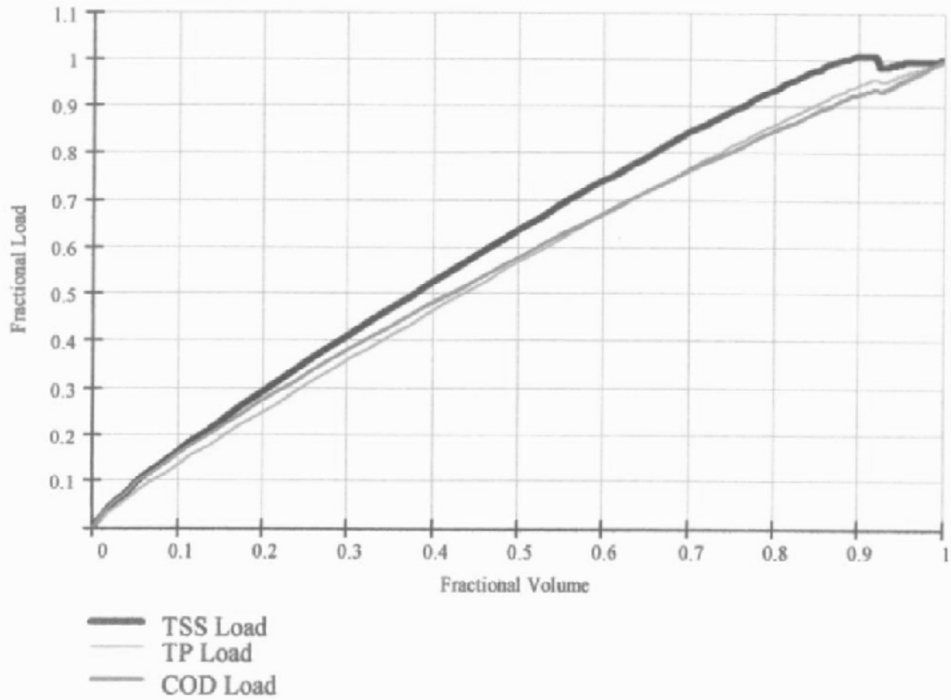


Figure G.17: Cumulative Load vs. Volume July 8, 1999 Site 1

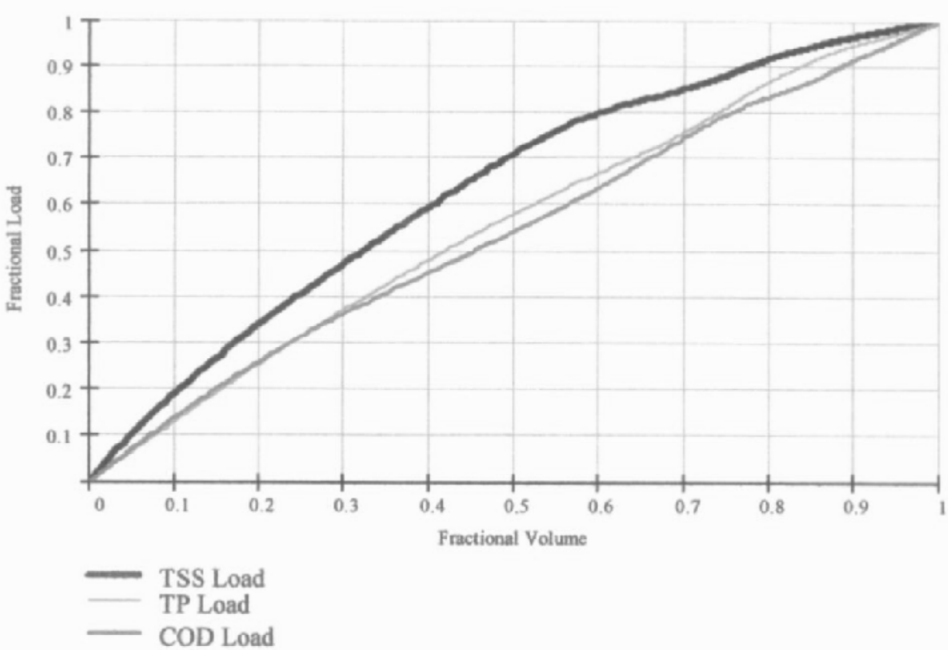


Figure G.18: Cumulative Load vs. Volume July 8, 1999 Site 2

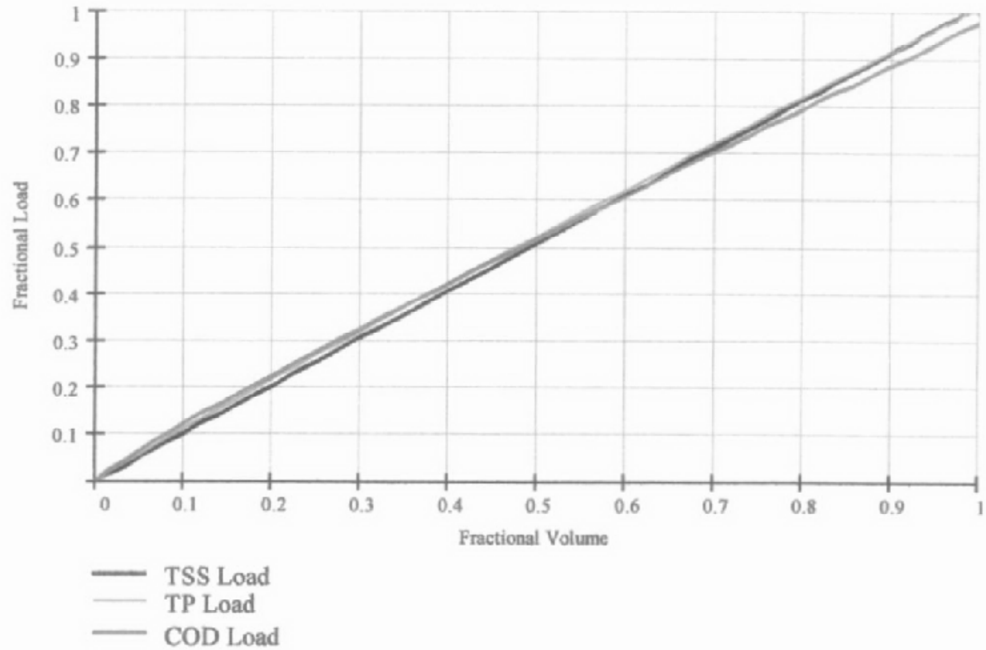


Figure G.19: Cumulative Load vs. Volume July 8, 1999 Site 3

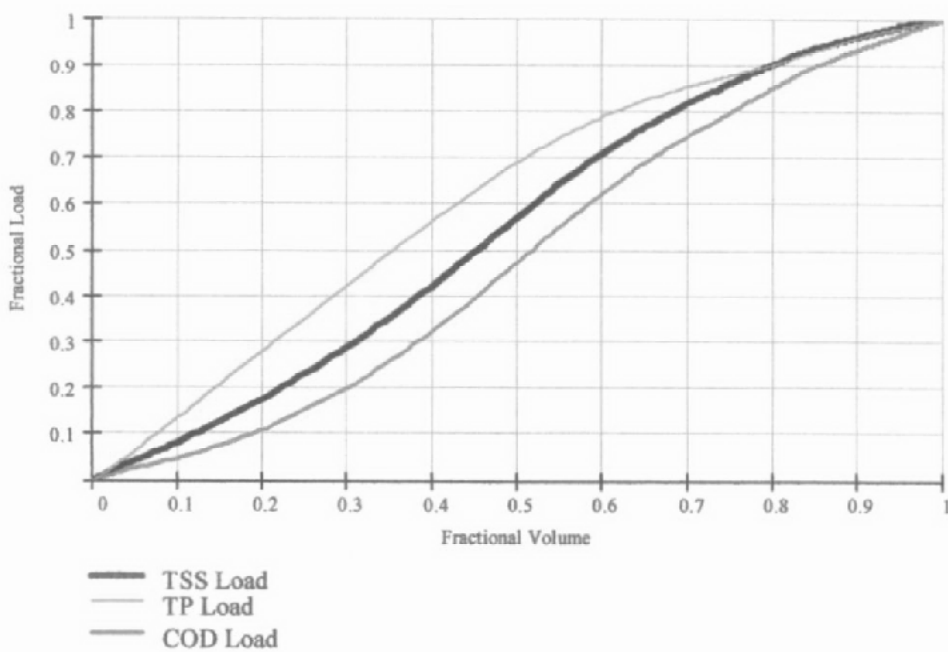


Figure G.20: Cumulative Load vs. Volume July 8, 1999 Site 4

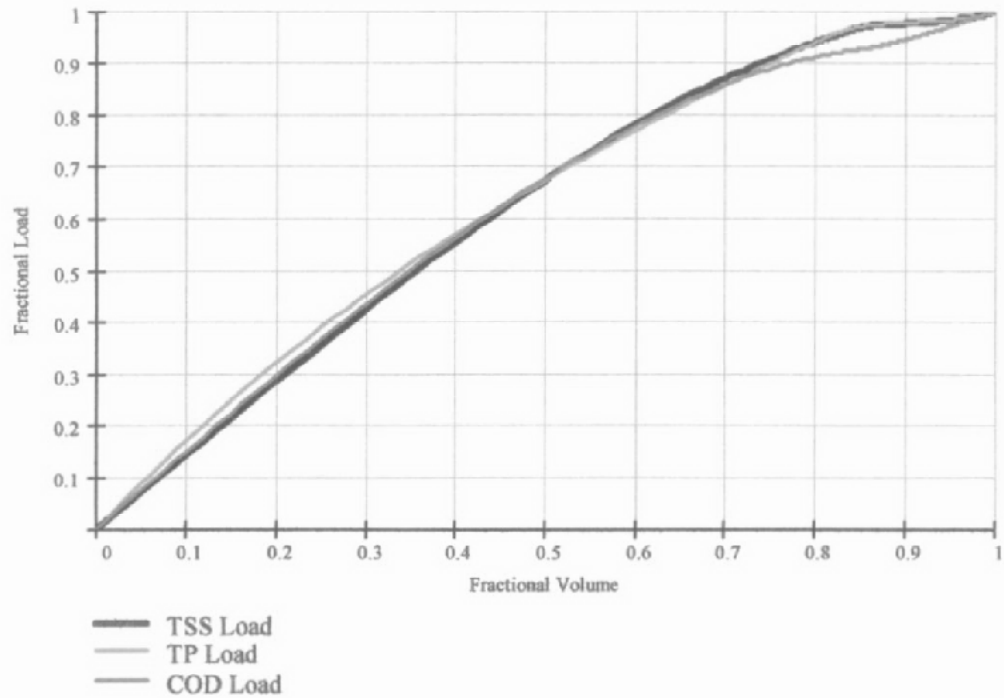


Figure G.21: Cumulative Load vs. Volume December 6, 1999 Site 1

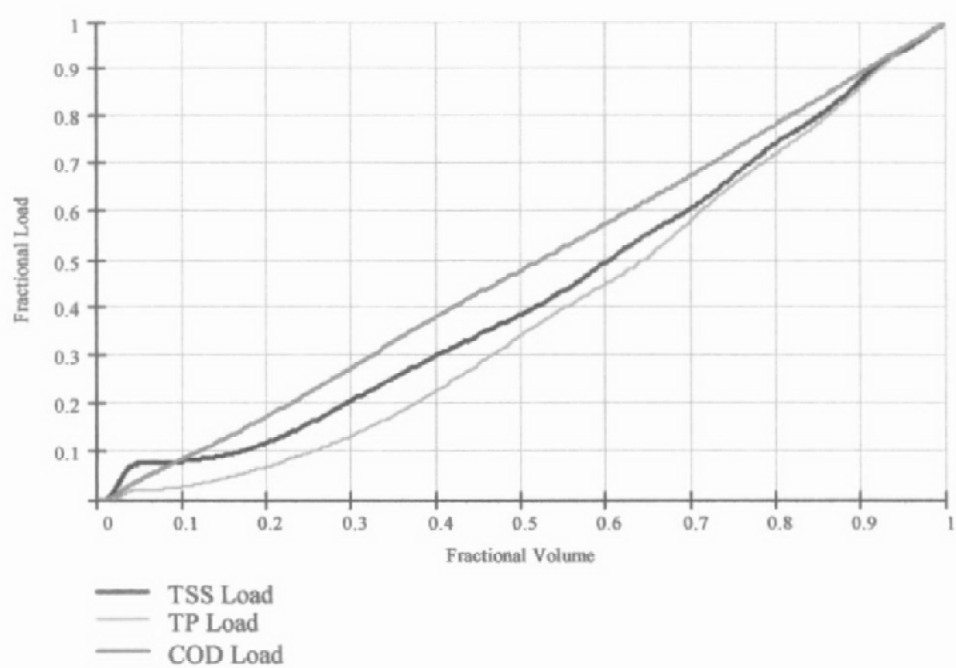


Figure G.22: Cumulative Load vs. Volume December 6, 1999 Site 2

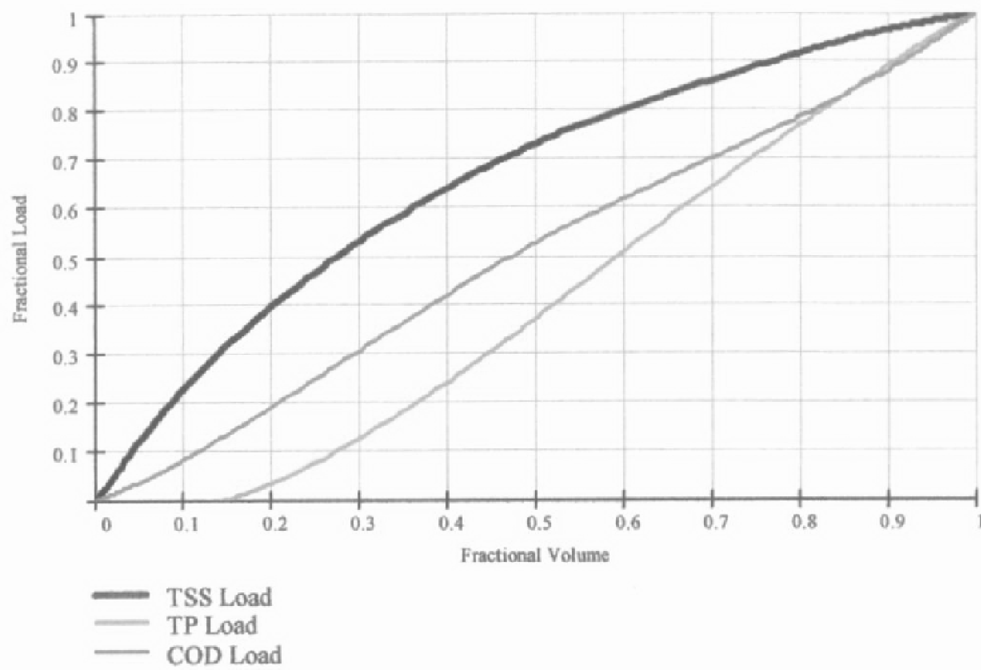


Figure G.23: Cumulative Load vs. Volume December 6, 1999 Site 3

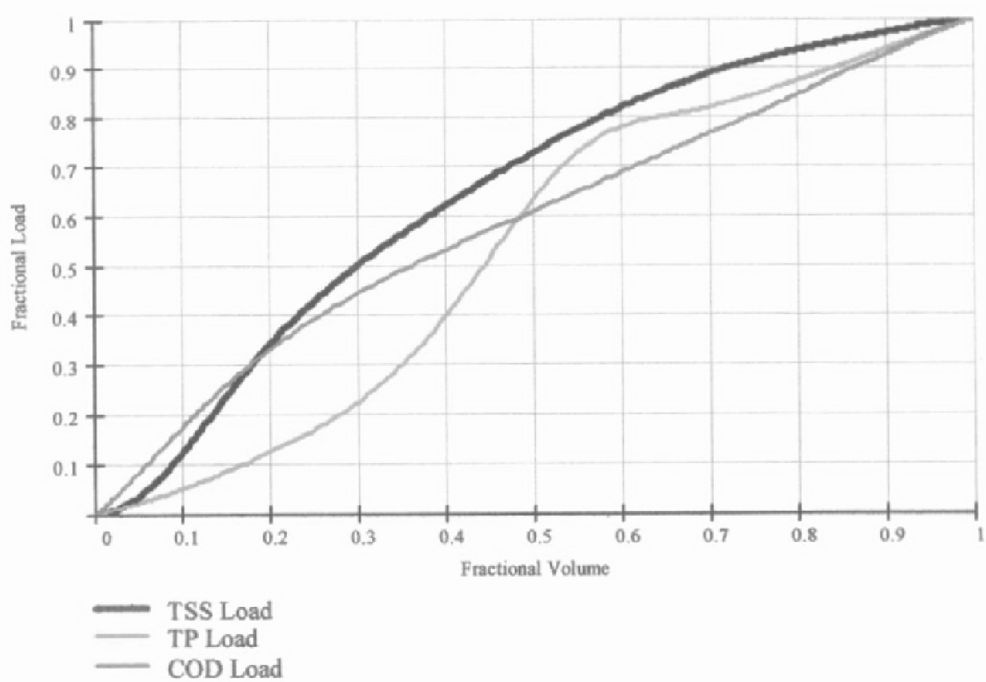


Figure G.24: Cumulative Load vs. Volume December 6, 1999 Site 4

Appendix H
Calculations & Graph for Cumulative Normal & Log Normal Distributions

Example Calculations for Normal and Log Normal Distributions in Mathcad

Flow data are contained in an ascii file called "Probability_TSS_Site_ 2." with an extension "txt". Mathcad command to read that file into the worksheet is:

DATA := READPRN("Probability_TSS_Site_2.txt")

DATA =

	0	1	2	3	4
0	176.39	0.957	2.246	0.2	-0.793
1	132.25	0.913	2.121	1.7	0.238
2	120.54	0.87	2.081	2.8	0.441
3	95.04	0.826	1.978	3.1	0.492
4	79.29	0.783	1.899	3.4	0.53
5	67.5	0.739	1.829	6.6	0.817
6	36.43	0.696	1.561	6.6	0.817
7	29.9	0.652	1.476	10.6	1.027
8	25.04	0.609	1.399	10.6	1.027
9	18.96	0.565	1.278	10.7	1.029
10	18.17	0.522	1.259	12.8	1.106
11	12.76	0.478	1.106	18.2	1.259
12	10.68	0.435	1.029	19	1.278
13	10.65	0.391	1.027	25	1.399
14	10.63	0.348	1.027	29.9	1.476

*Note Mathcad shows only 14 of the total number of rows in the above matrix to conserve on space

$i := 0, 1 .. 21$ Number of data/row in matrix

Column 0 = TSS values in descending order
Column 1 = ranking of the values
Column 2 = log of the values
Column 3 = TSS values in ascending order
Column 4 = log values for column 3

DATA is divided up into five individual vectors. Each column is identified as to the contents.

$\text{ranked\_data}_i := \text{DATA}_{i,0} \cdot \frac{\text{lb}}{\text{acre} \cdot \text{in}}$ = original TSS values in descending order

$\text{ln\_data}_i := \ln\left(\frac{\text{ranked\_data}_{i,0}}{\frac{\text{lb}}{\text{acre} \cdot \text{in}}}\right)$ = ln of each data value

$\text{ln\_mean} := \text{mean}(\text{ln\_data})$ = logmean of the data

$\text{ln\_stdev} := \text{stdev}(\text{ln\_data})$ = logmean of the standard deviation for the data

$\text{prob}_i := \frac{i+1}{\text{rows}(\text{DATA})+1}$ = compute the observed probability of occurrence using the ranked data

$\mu := \text{mean}(\text{ranked\_data})$ $\sigma := \text{stdev}(\text{ranked\_data})$

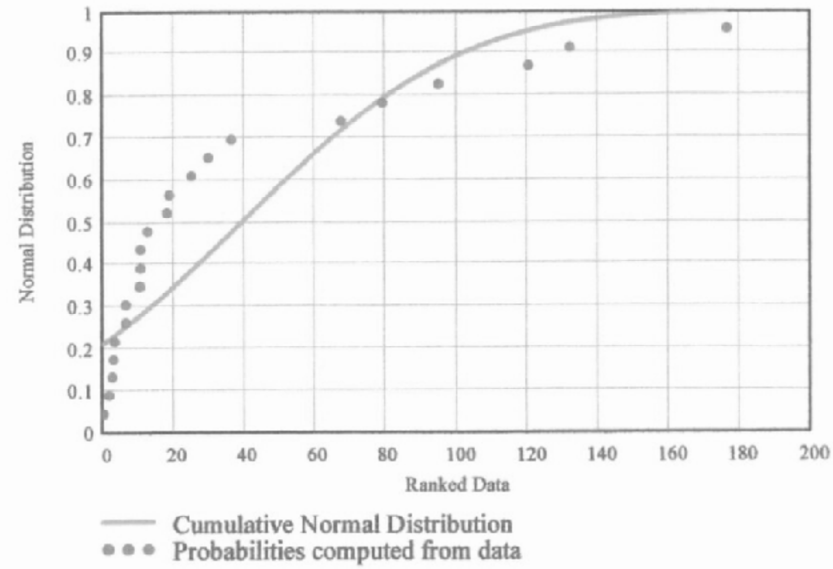
$\mu = 39.478 \cdot \frac{\text{lb}}{\text{acre} \cdot \text{in}}$ = mean of ranked data $\sigma = 49.028 \cdot \frac{\text{lb}}{\text{acre} \cdot \text{in}}$ = std deviation of ranked data

$\text{dnorm}(x, \mu, \sigma)$ = normal distribution

$\text{pnorm}(x, \mu, \sigma)$ = cumulative normal distribution

$x := 0 \cdot \frac{\text{lb}}{\text{acre} \cdot \text{in}}, 0.01 \cdot \frac{\text{lb}}{\text{acre} \cdot \text{in}} .. 176.4 \cdot \frac{\text{lb}}{\text{acre} \cdot \text{in}}$ = variable covering range of yield values, to be us in statistical distributions

$x1 := 0 \cdot \frac{\text{lb}}{\text{acre} \cdot \text{in}}, 0.01 \cdot \frac{\text{lb}}{\text{acre} \cdot \text{in}} .. 180 \cdot \frac{\text{lb}}{\text{acre} \cdot \text{in}}$ = variable covering range of yield values, to be us in log normal distribution



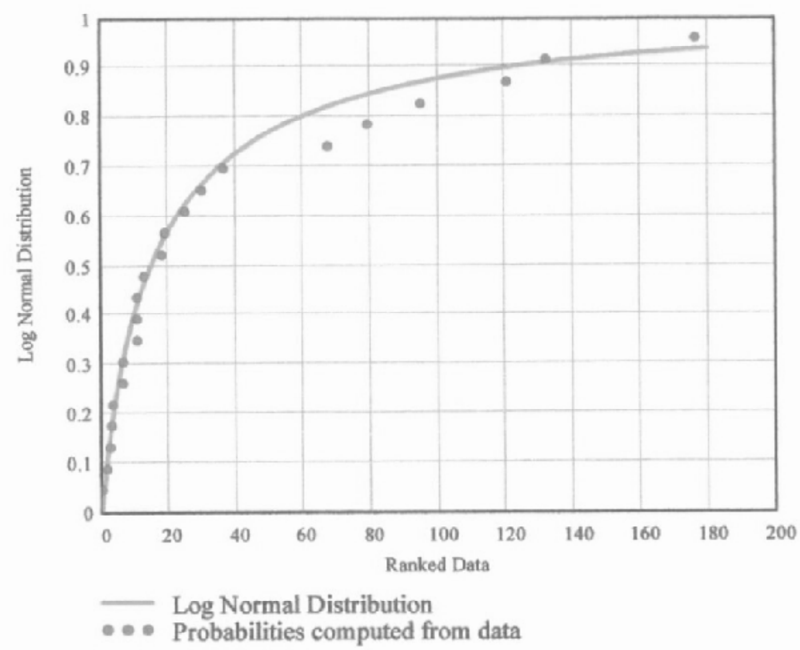
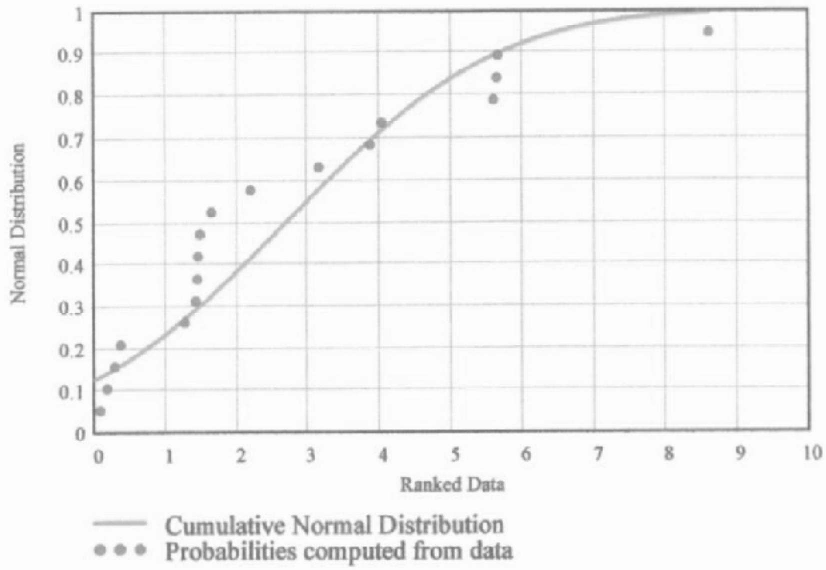


Figure H.1: Cumulative Normal Distribution and Log Normal Distribution for Site 2 TSS



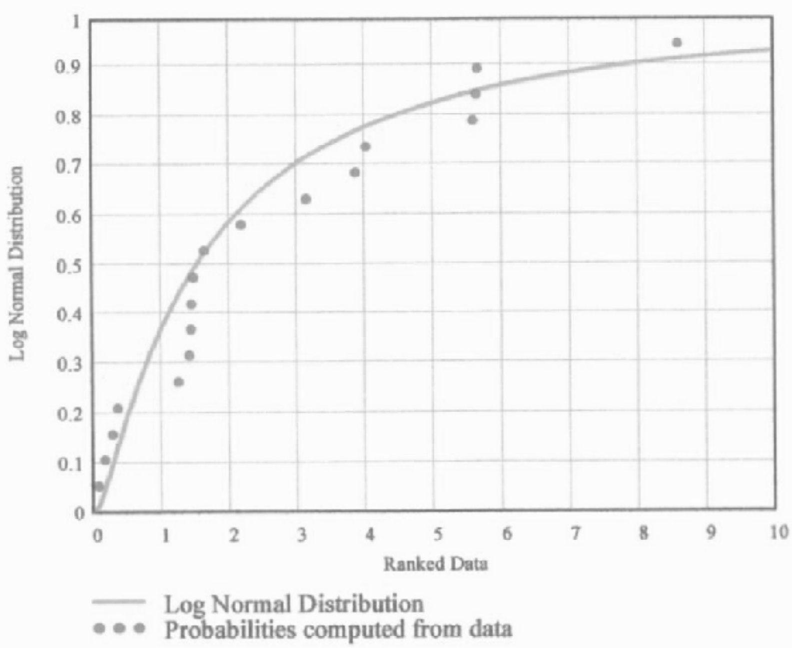
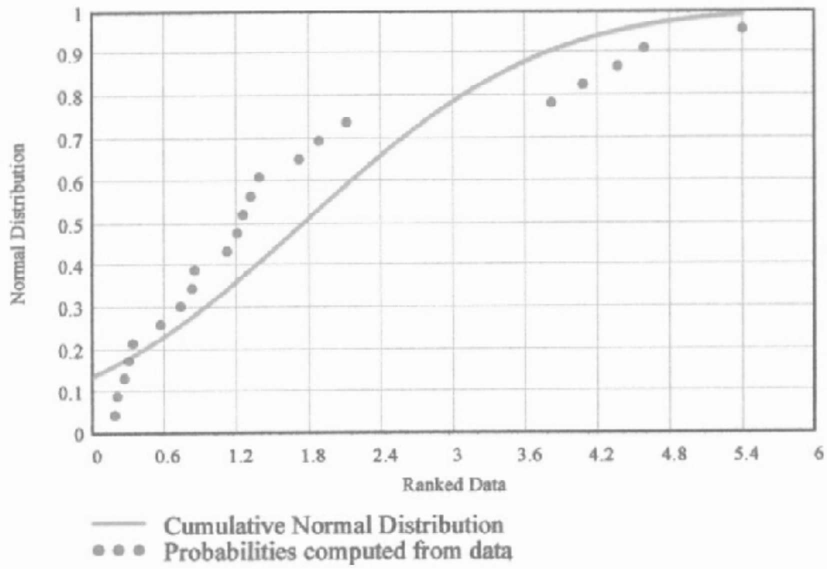


Figure H.2: Site 1 COD Normal and Log Normal Distribution



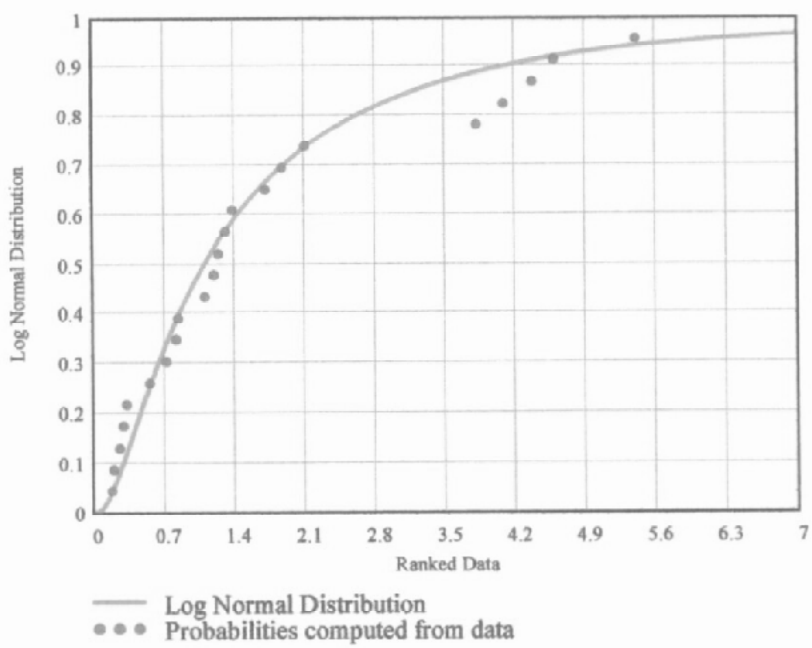
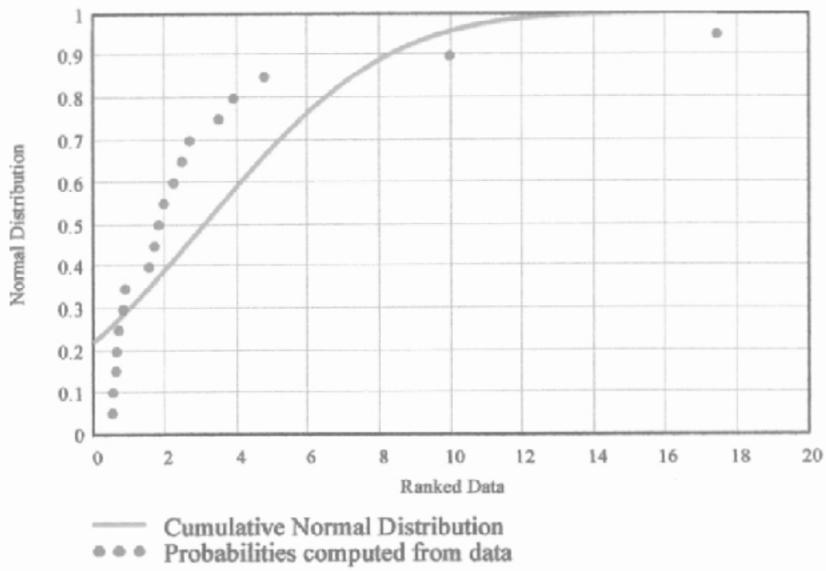


Figure H.3: Site 2 COD Normal and Log Normal Distribution



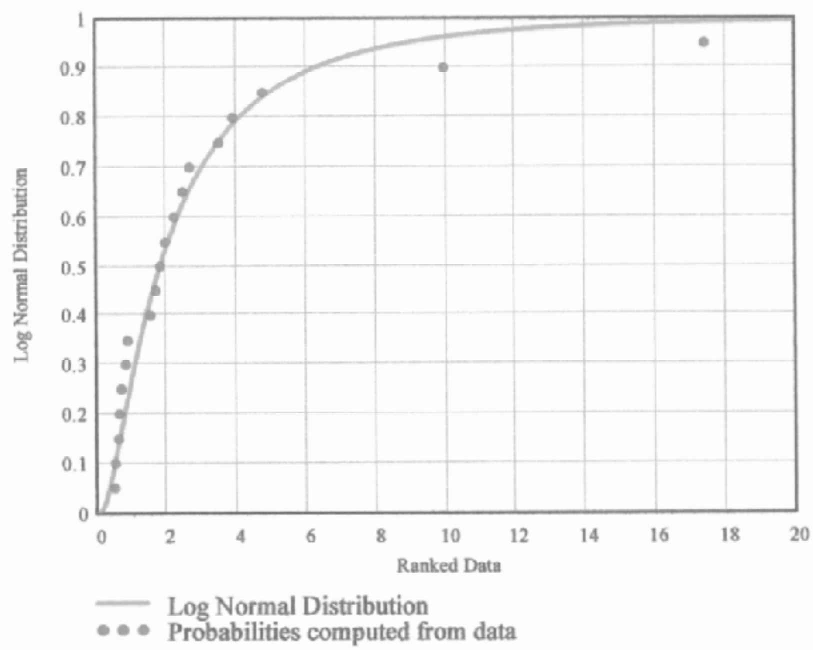
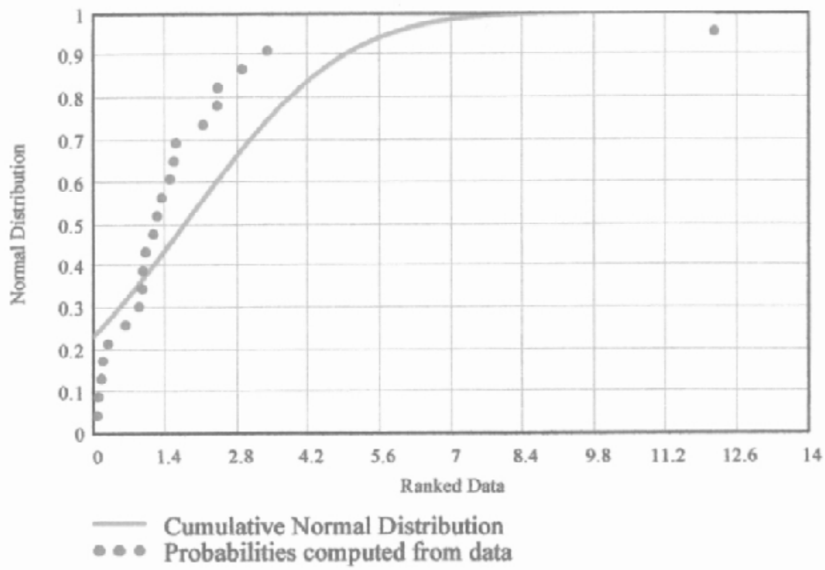


Figure H.4: Site 3 COD Normal and Log Normal Distribution



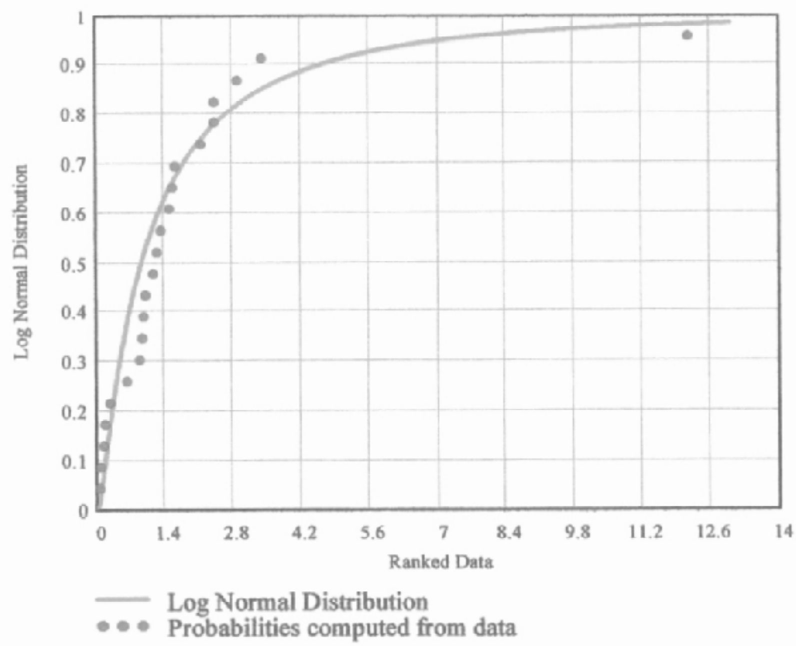
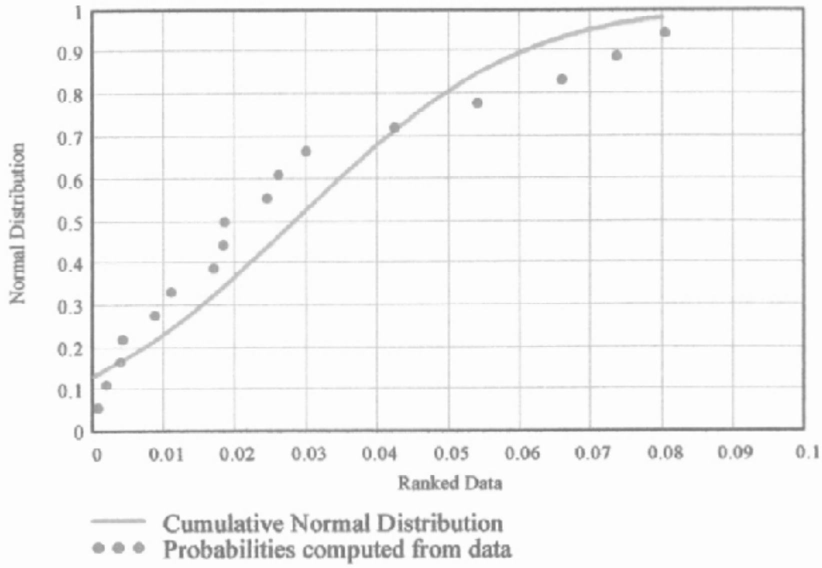


Figure H.5: Site 4 COD Normal and Log Normal Distribution



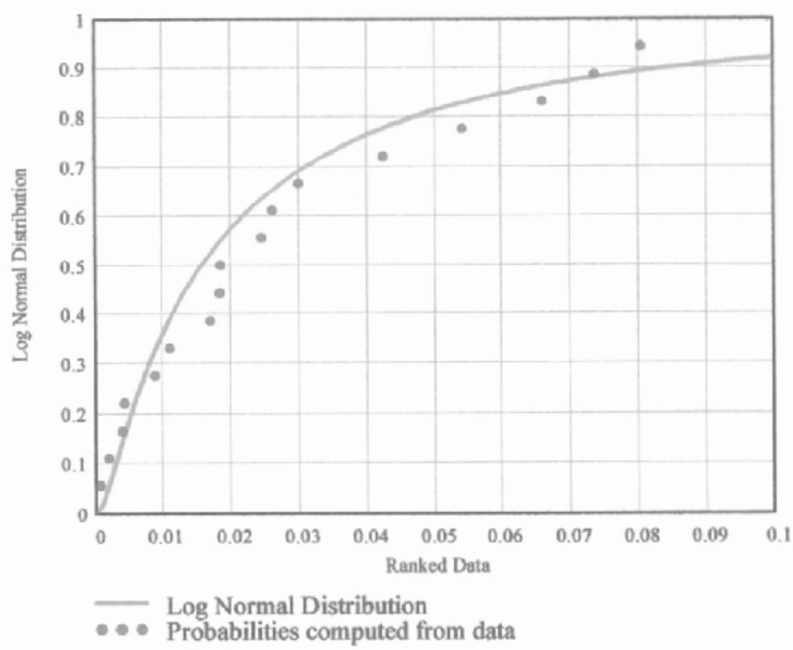
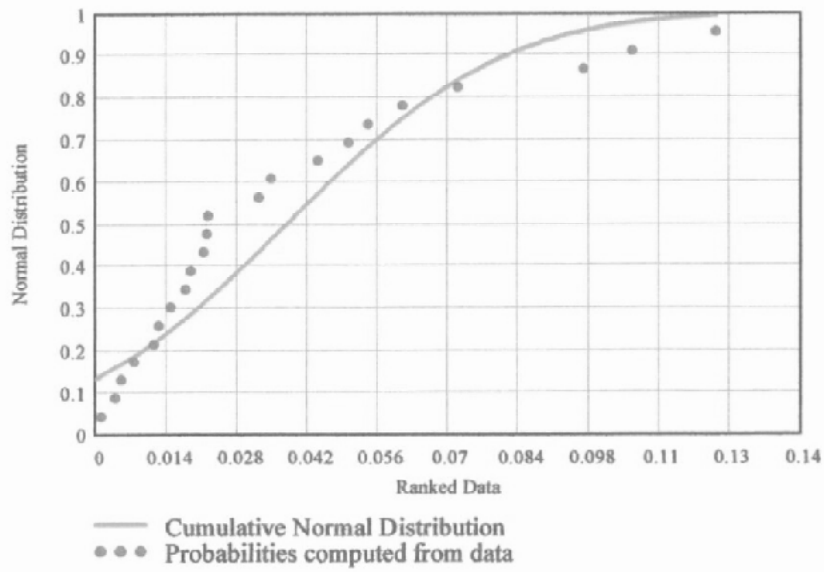


Figure H.6: Site 1 TP Normal and Log Normal Distribution



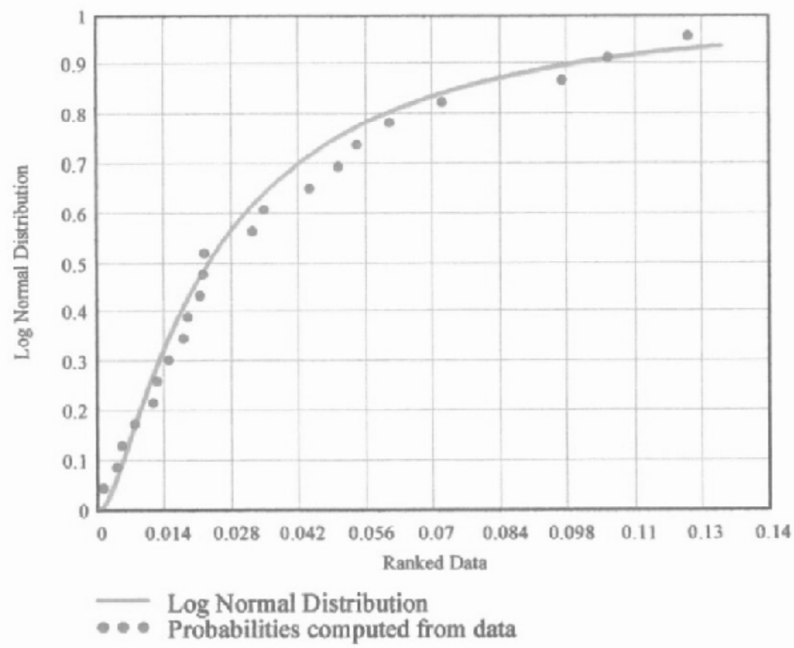
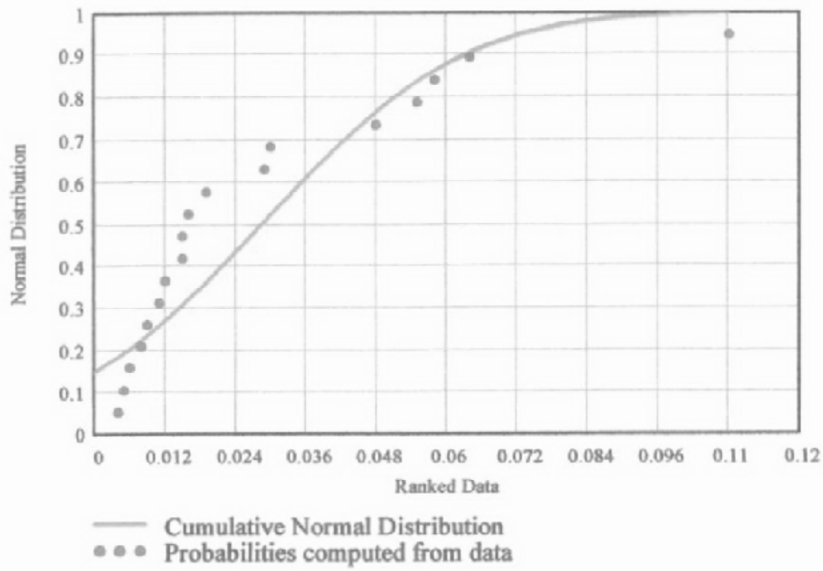


Figure H.7: Site 2 TP Normal and Log Normal Distribution



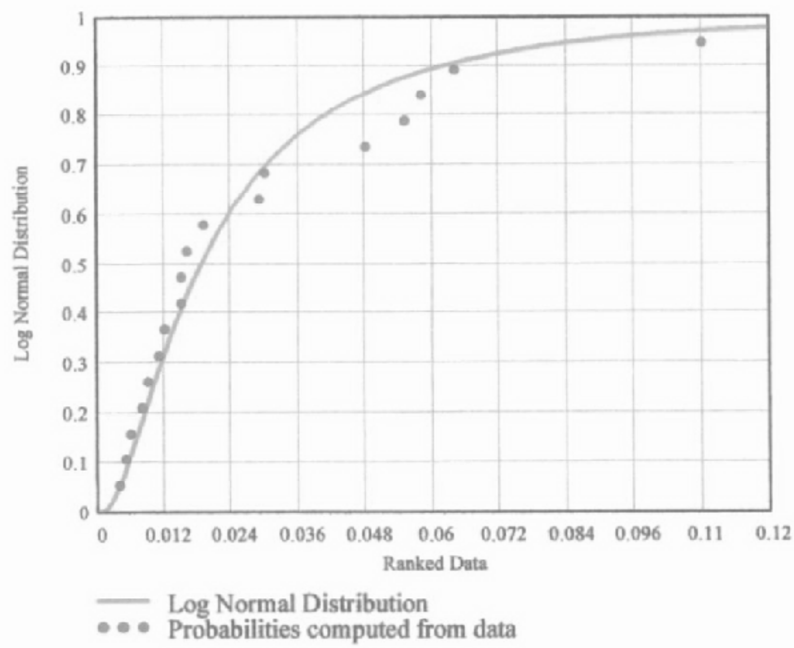
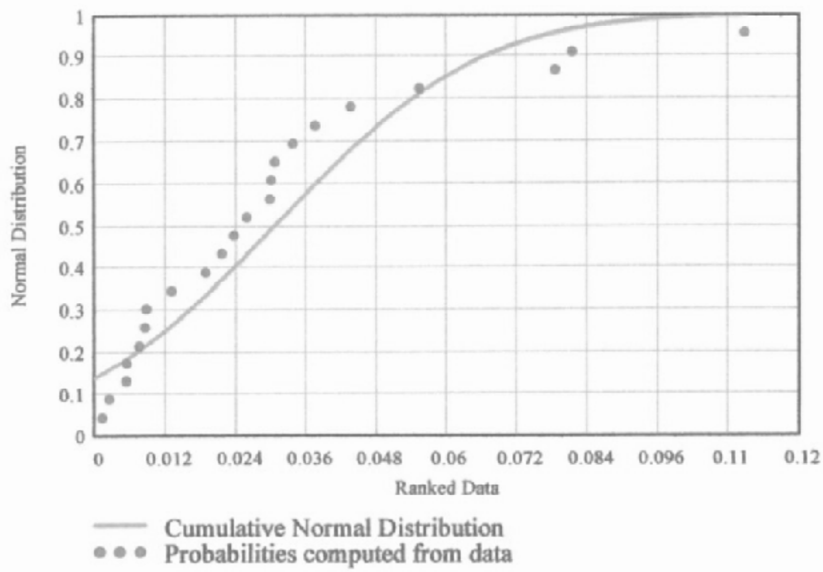


Figure H.8: Site 3 TP Normal and Log Normal Distribution



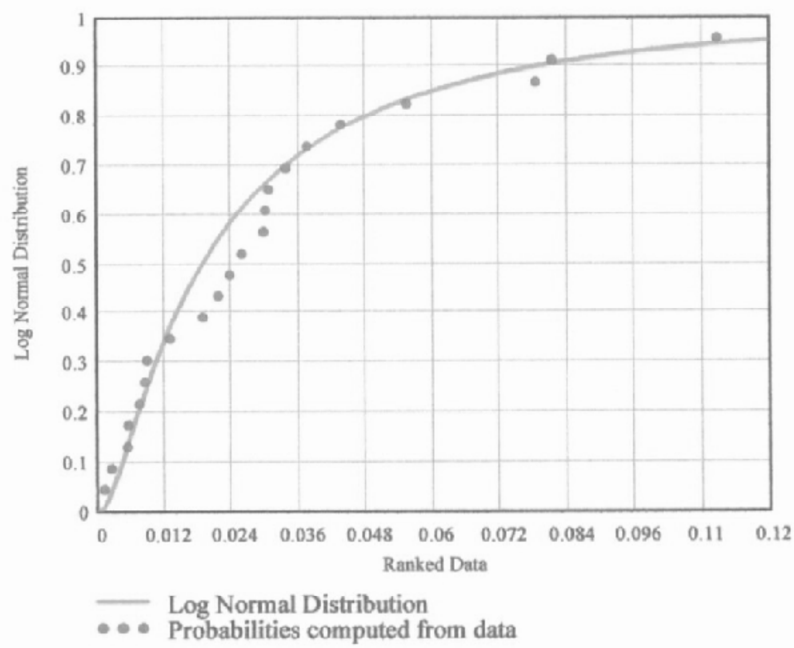
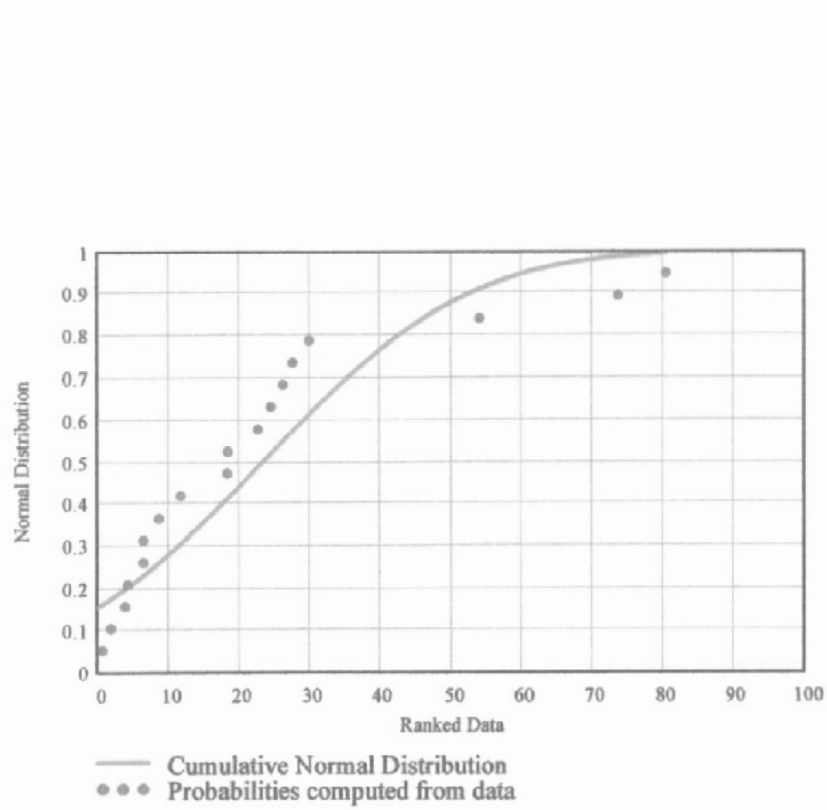


Figure H.9: Site 4 TP Normal and Log Normal Distribution



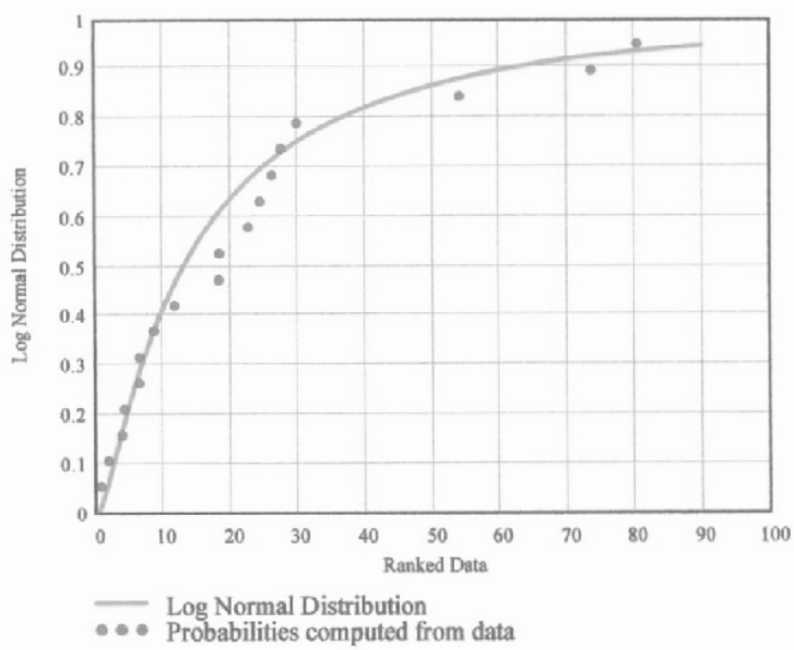
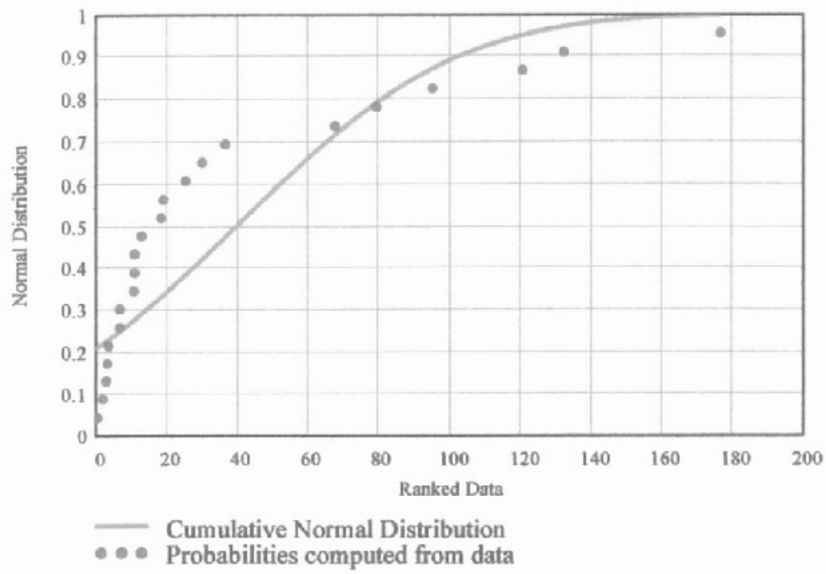


Figure H.10: Site 1 TSS Normal and Log Normal Distribution



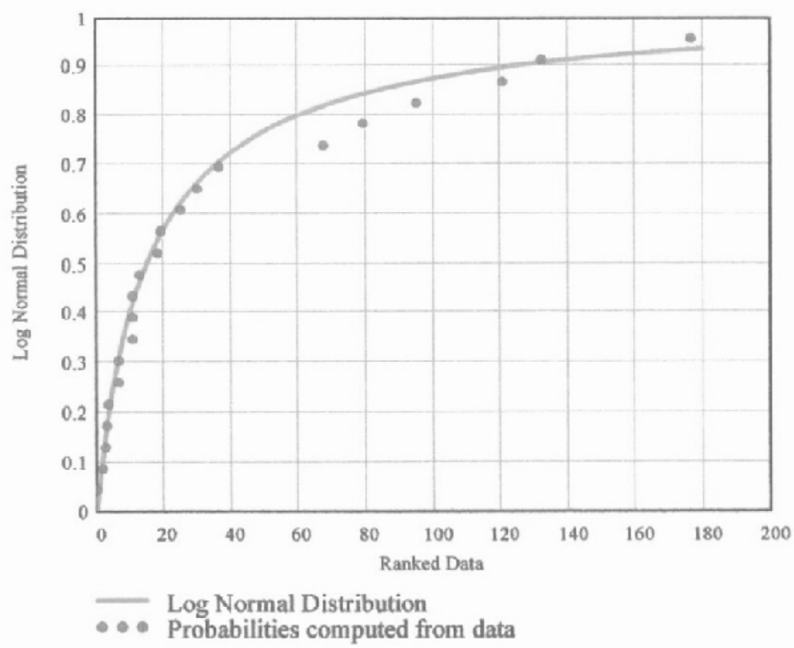
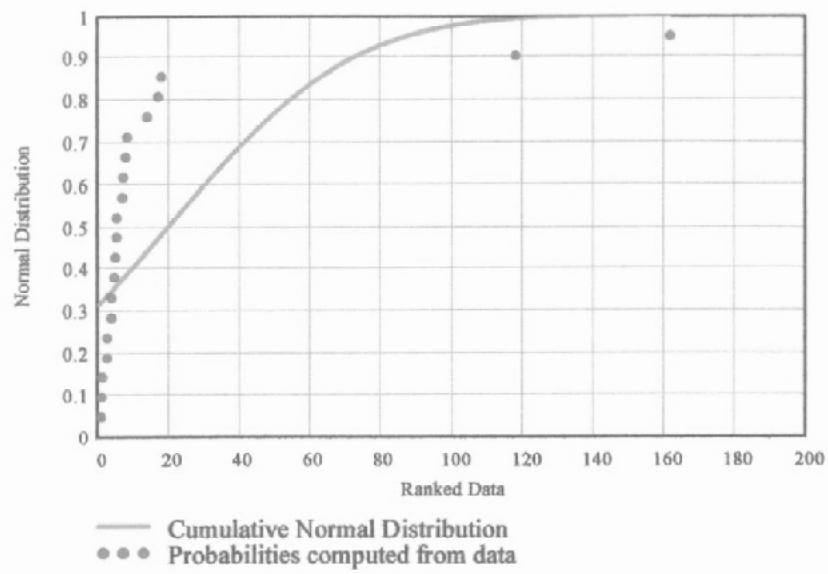


Figure H.11: Site 2 TSS Normal and Log Normal Distribution



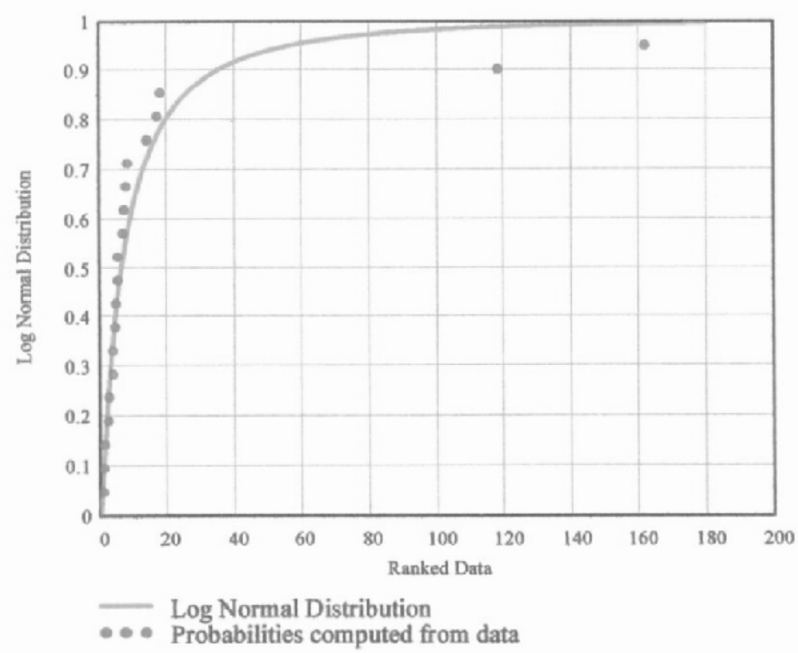
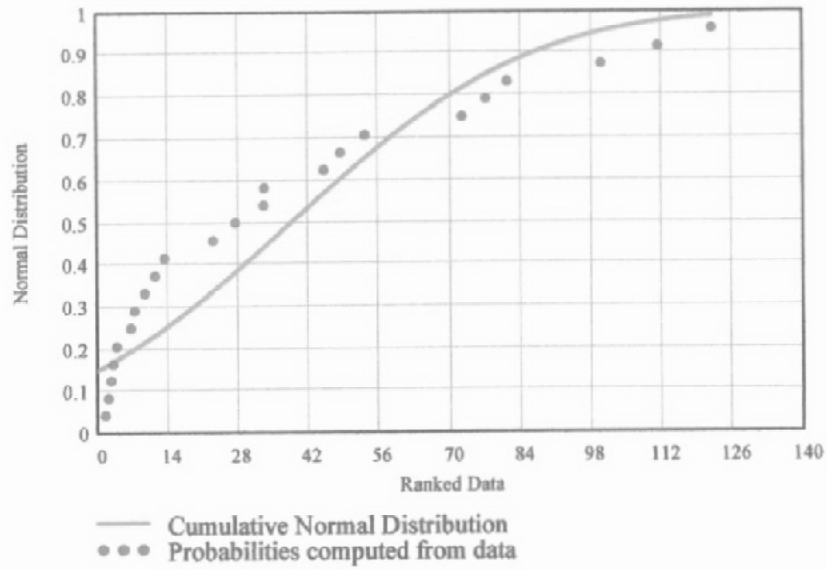


Figure H.12: Site 3 TSS Normal and Log Normal Distribution



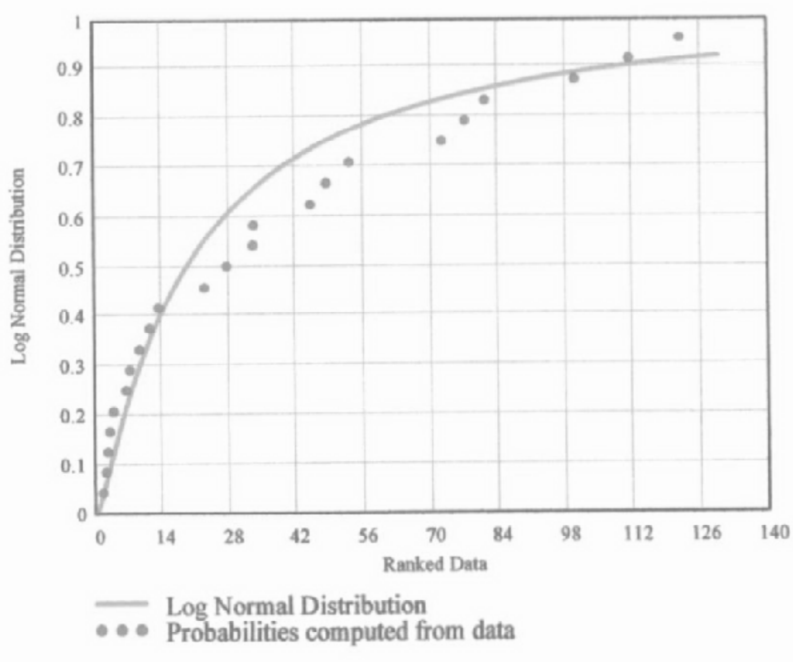
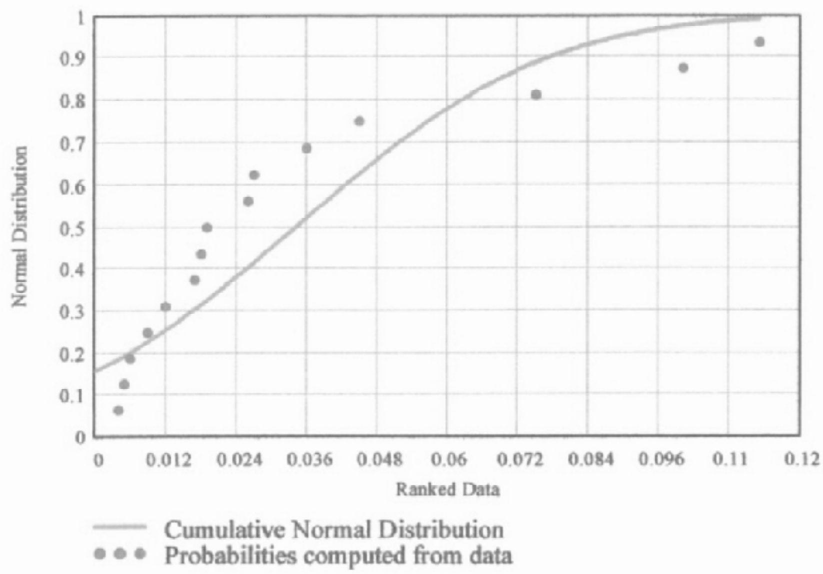


Figure H.13: Site 4 TSS Normal and Log Normal Distribution



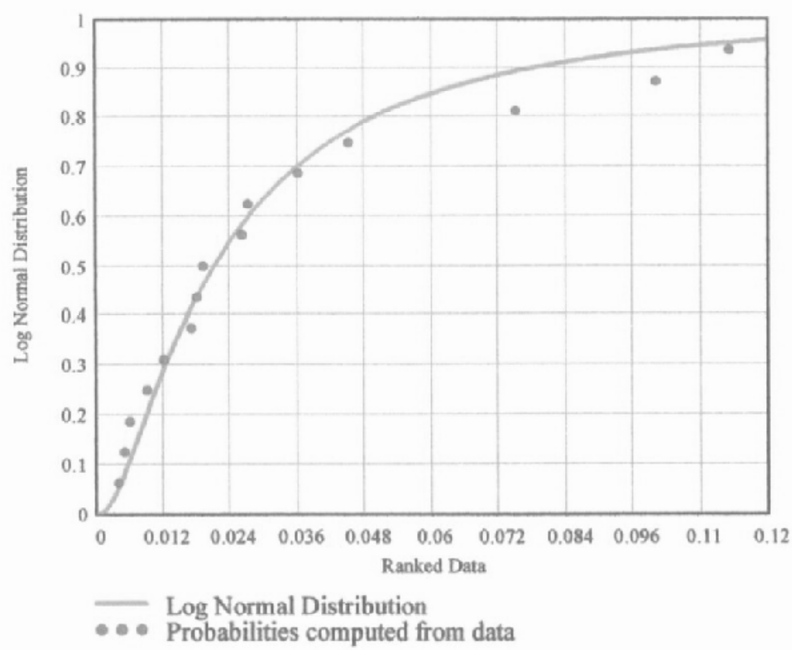
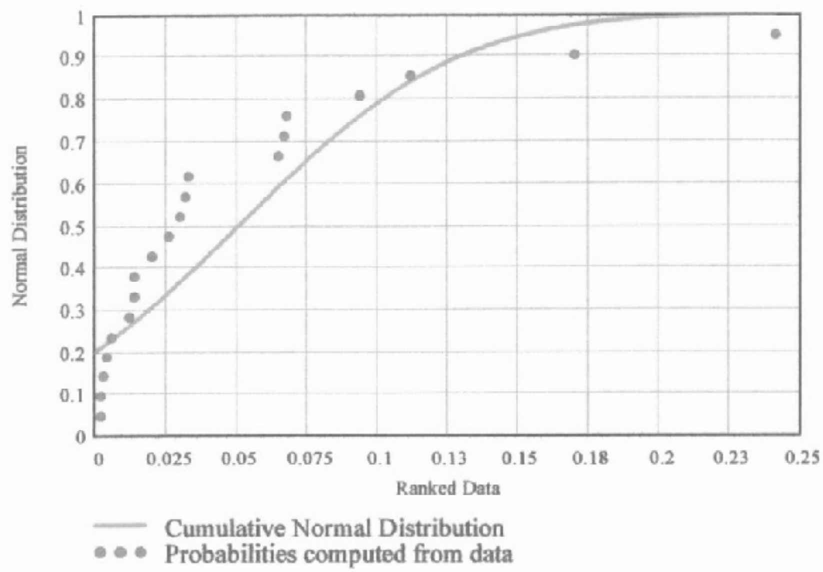


Figure H.14: Site 1 NH_3 Normal and Log Normal Distribution



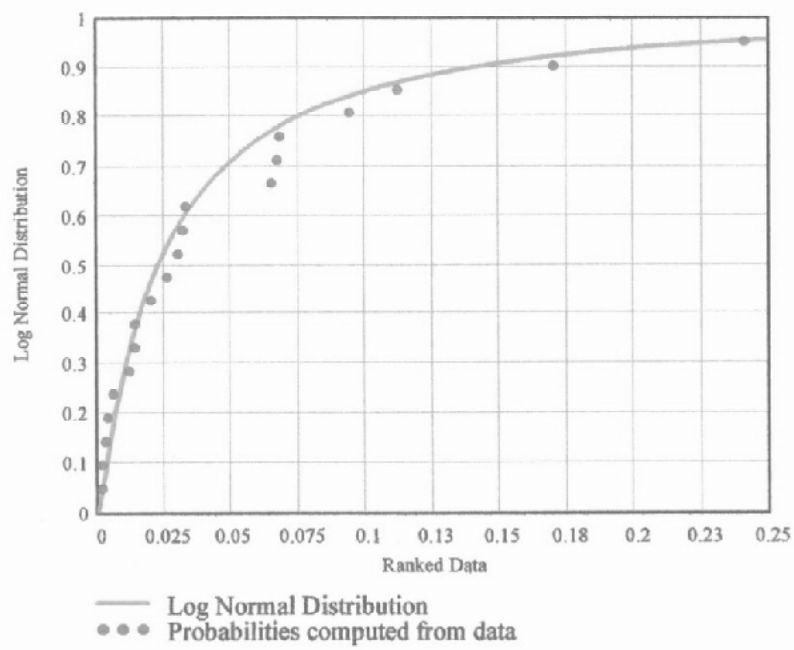
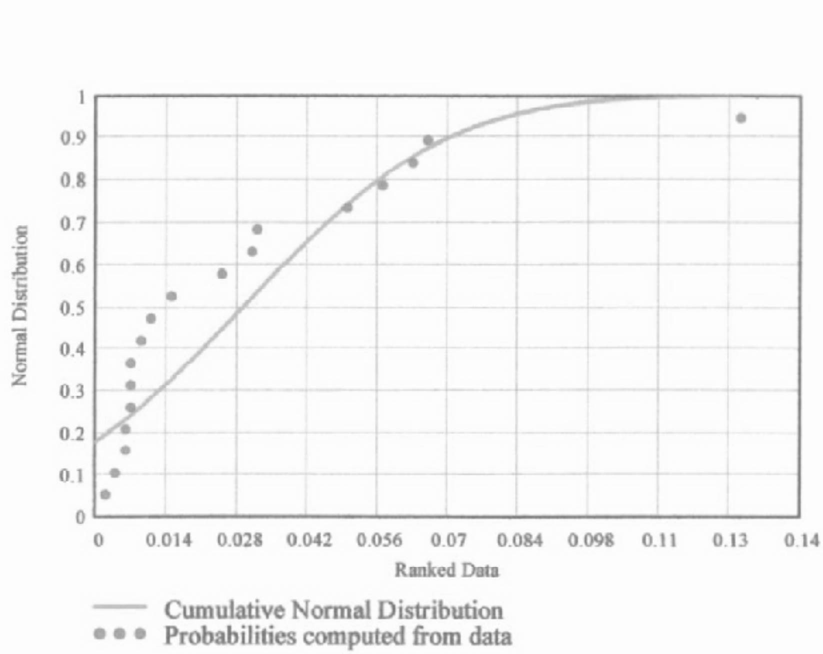


Figure H.15: Site 2 NH_3 Normal and Log Normal Distribution



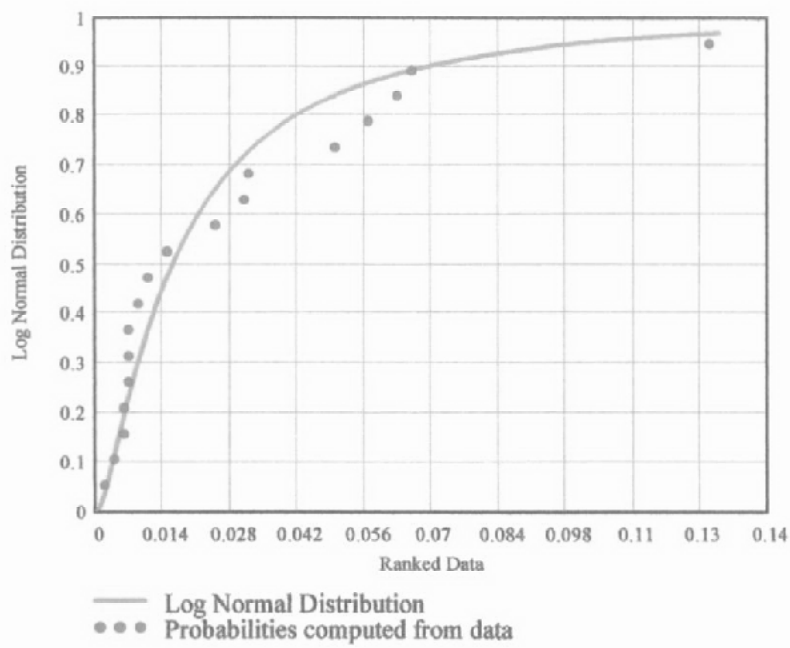
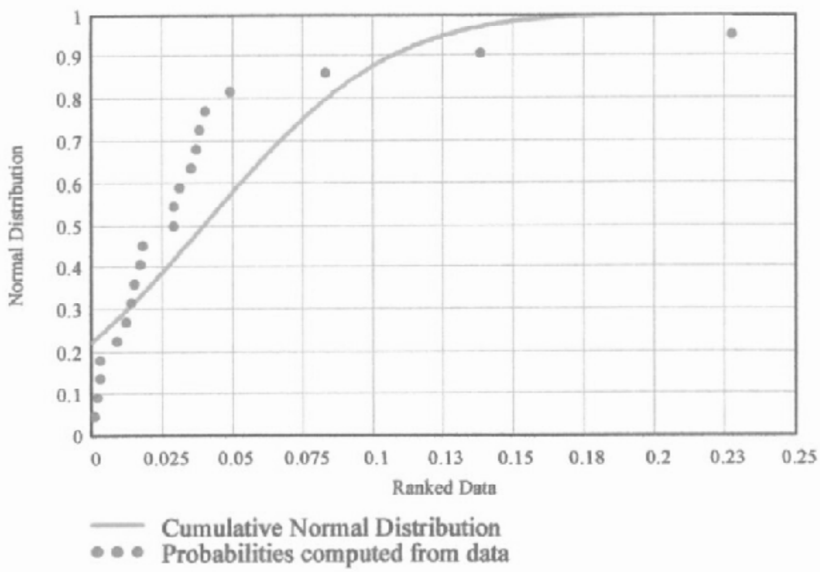


Figure H.16: Site 3 NH_3 Normal and Log Normal Distribution



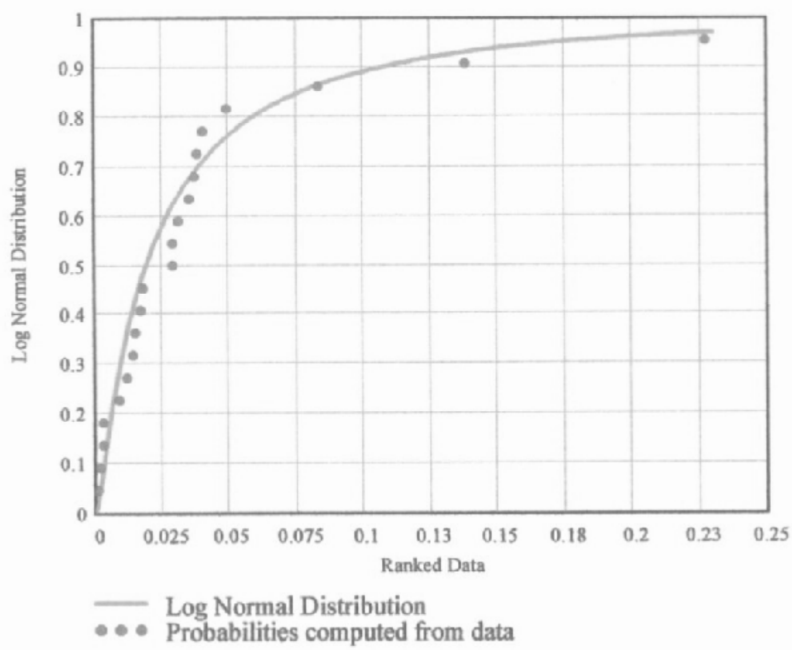
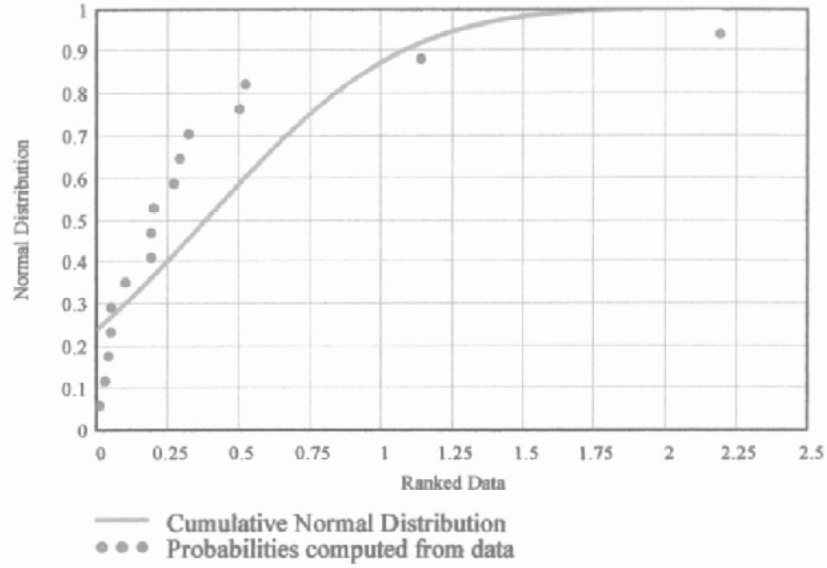


Figure H.17: Site 4 NH_3 Normal and Log Normal Distribution



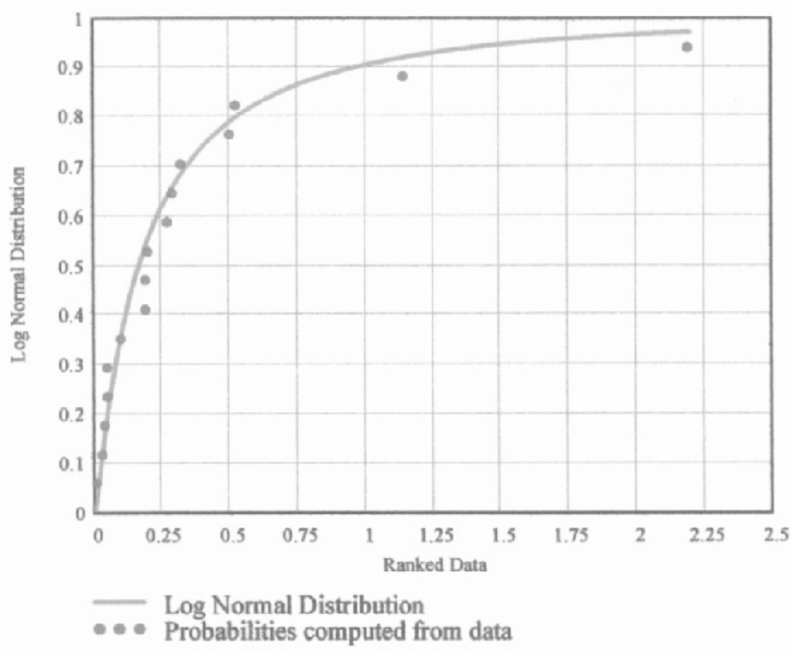
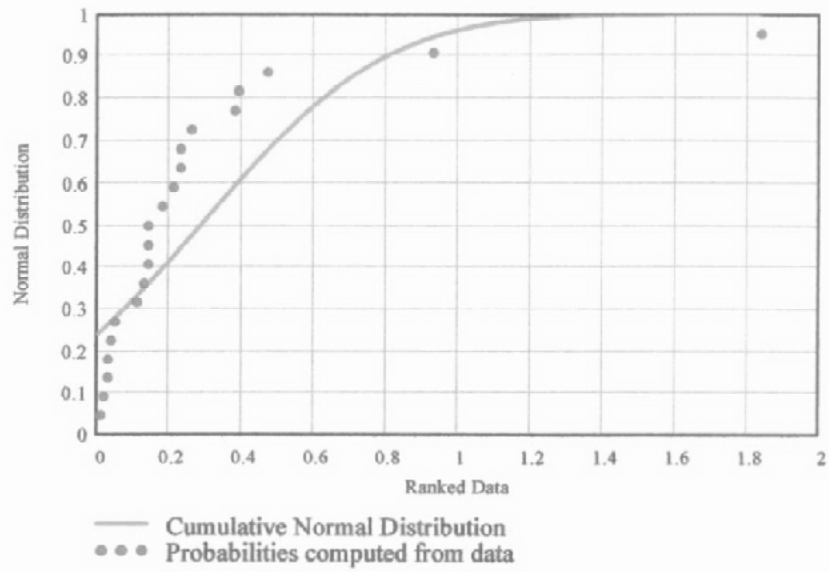


Figure H.18: Site 1 NO_3 Normal and Log Normal Distribution



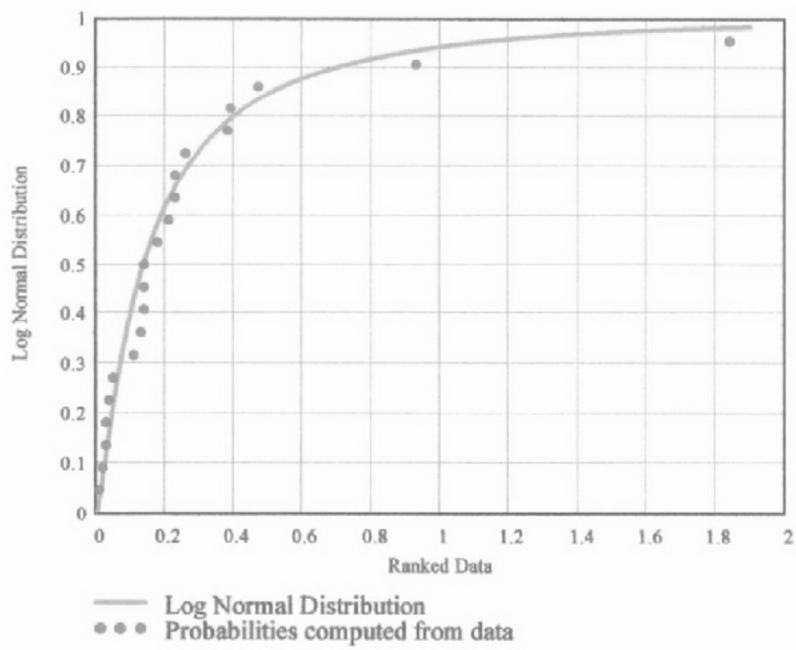
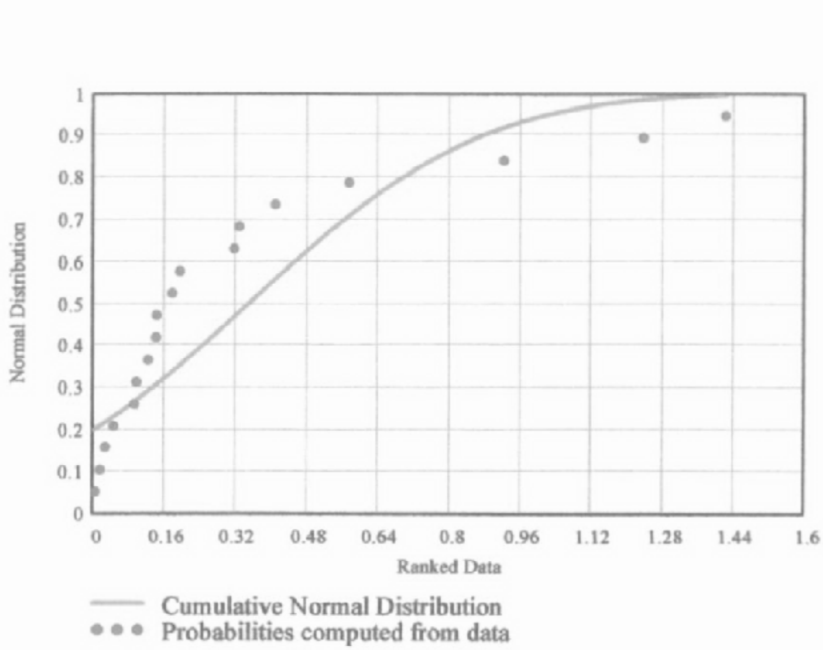


Figure H.19: Site 2 NO_3 Normal and Log Normal Distribution



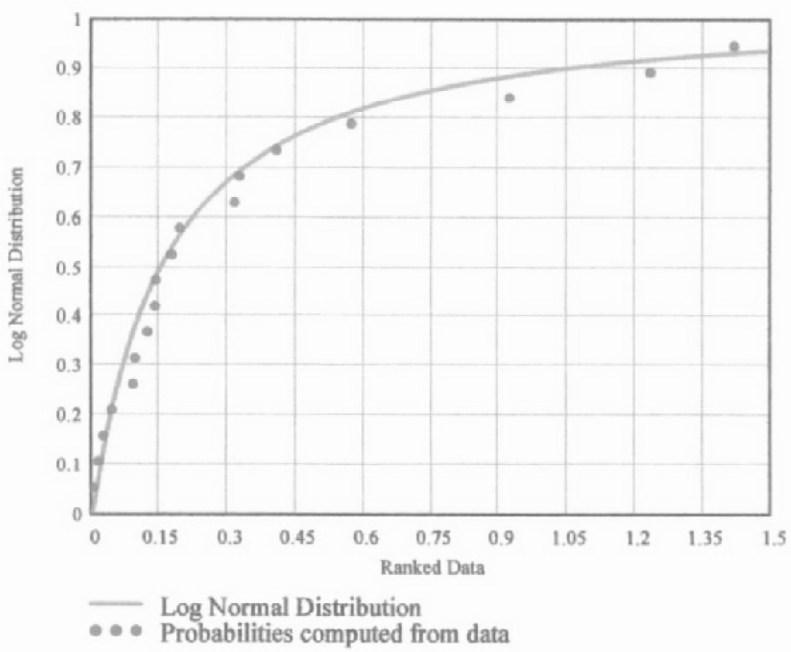
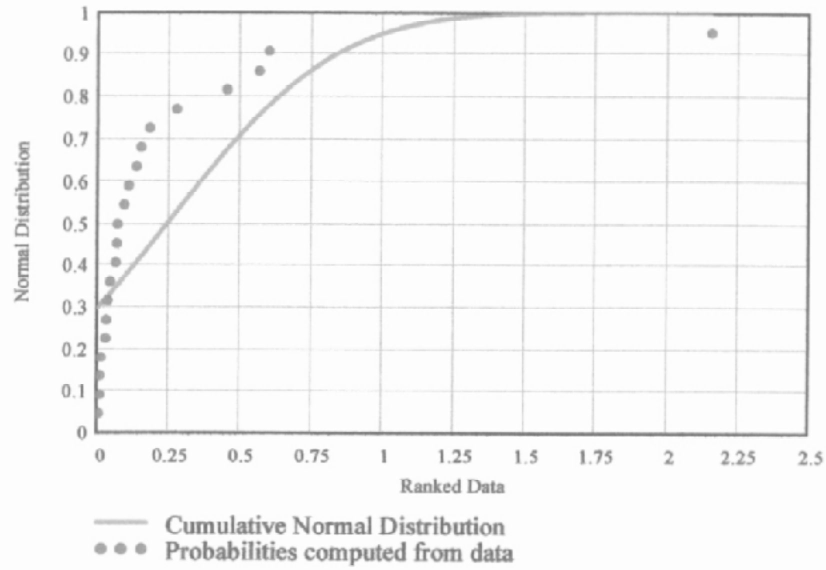


Figure H.20: Site 3 NO_3 Normal and Log Normal Distribution



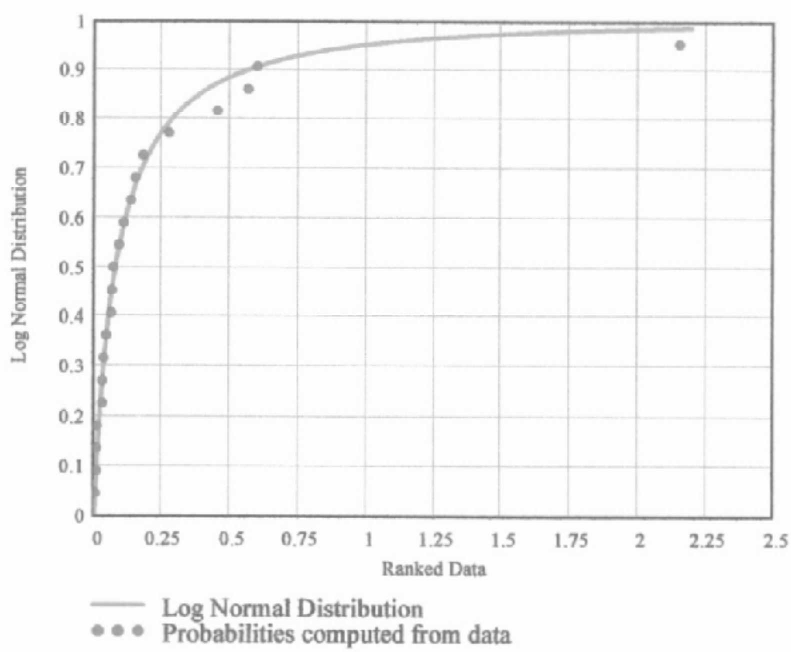


Figure H.21: Site 4 NO_3 Normal and Log Normal Distribution

Appendix I
Examples of the Kruskal-Wallis
and
Mann-Whitney Test

The Kruskal-Wallis Test

Reference: Statistical Procedures for Analysis of Environmental Data and Risk Assessment, Edward A. Mcbean and Frank A. Rovers, Prentice Hall, 1998

Introduction: The Kruskal-Wallis test is a generalization of the Mann-Whitney U test. The generalization is to k populations where k may now be larger than 2. Otherwise the null hypothesis being tested is the same, that is all groups come from identical distributions.

In this problem we have pollutant loadings expressed as lbs/acre/in rainfall from four different catchments. We want to know if it can be assumed that all the values came from identical distributions OR if the distribution from some catchments are, in fact, different.

H_0: null hypothesis - the k populations follow the *same* distribution

The statements below read in the data from each site as ASCII files

SITE1 :=

A:\TSS Load Pounds per Inch Rain per Acre site 1.txt

SITE2 :=

A:\TSS Load Pounds per Inch Rain per Acre site 2.txt

SITE3 :=

A:\TSS Load Pounds per Inch Rain per Acre site 3.txt

SITE4 :=

A:\TSS Load Pounds per Inch Rain per Acre site 4.txt

Conditions and assumptions

The Test Statistic

The Kruskal-Wallis test statistic K is, once again, a function of ranks of pooled data. The calculation requires many constructs including accounting for ties.

$k := 4$ <==== the number of data sets

$n_0 :=$ length(SITE1) $n_2 :=$ length(SITE3)

$n_1 :=$ length(SITE2) $n_3 :=$ length(SITE4)

$$n = \begin{bmatrix} 18 \\ 22 \\ 19 \\ 23 \end{bmatrix}$$ <==== the number in each sample

$N := \sum n$ $N = 82$ <==== the total number of data points

The computation of K begins by tagging each data set :

$i0 := 0 .. n_0 - 1$ $i1 := 0 .. n_1 - 1$

$SITE1_{i0,1} := 0$ $SITE2_{i1,1} := 1$

$i2 := 0 .. n_2 - 1$ $i3 := 0 .. n_3 - 1$

$SITE3_{i2,1} := 2$ $SITE4_{i3,1} := 3$

Then pool the data by augmenting the four vectors, call the matrix "D". Each vector must have the same number of rows for the augmentation function to work, this is why they are transposed.

$$D := \text{augment}\left(SITE1^T, \text{augment}\left(SITE2^T, \text{augment}\left(SITE3^T, SITE4^T\right)\right)\right)^T$$

D =

6.4	0
6.5	0
73.6	0
3.9	0
1.9	0
24.4	0
0.7	0
4.2	0
18.3	0
29.9	0
18.4	0
54.1	0
8.7	0
80.4	0
26.2	0

If you scroll through this matrix we have all four data sets stacked on top of each other. The first column shows the data set number.

Now, sort the data based on the first column of the pooled data matrix $D := \text{csort}(D, 0)$. This produces a matrix with the loadings from all four sites in ascending order. The "tags" have been carried along with the data values.

D =

0.2	1
0.7	0
0.9	2
1.1	2
1.3	2
1.5	3
1.7	1
1.9	0
2.2	3
2.5	2
2.6	2
2.7	3
2.8	1

D matrix sorted by column zero

assign ranks using averages when necessary

$i := 1 .. N - 1$ a counter, steps through all data values

$u_0 := \left(D^{<0>}\right)_0$ set u_0 equal to the first loading value

$I_0 := 0$ vector for ranks, set initial value equal to zero

The statement below is a "conditional". It takes the first value of the "i" column of the sorted matrix and compares it to the "i-1" value. IF they are equal then the vector u remains unchanged. If they are not then the u vector is augmented with the value. In this way we create a vector where each distinct value occurs only <u>once</u>.

$$u^{<0 \cdot i>} := \mathrm{if}\left[\left(D^{<0>}\right)_i = \left(D^{<0>}\right)_{i-1}, u, \mathrm{augment}\left[u^T, \left(D^{<0>}\right)_i\right]^T\right]$$

Note that the arguments of the augment function are transposed. This is usually the case. It is because the augment function requires vectors with the same number of rows. Any transposed vector has 1 row, regardless of the number of elements, and thus any two transposed vectors can be augmented.

$u = 0.2$

Scroll through the vector, the resulting u vector contains each loading value <u>only once</u>

The statement below is also a "conditional". It takes the first value of the "i" column of the sorted matrix and compares it to the "i-1" value. IF they are equal then the vector I remains unchanged. If they are not then the I vector is augmented with the value of the counter i. In this way we create a vector corresponding to the u vector where each distinct value has a unique rank.

$$I^{<0 \cdot i>} := \mathrm{if}\left[\left(D^{<0>}\right)_i = \left(D^{<0>}\right)_{i-1}, I, \mathrm{augment}\left(I^T, i\right)^T\right]$$

$l = 0$ note : rank 14 dropped due to duplicate values

Now create a variable "f" which turns out to be the number of times each distinct value occurred. This is done by subtracting sequential values of the index variable.

$$j := 0 .. \mathrm{last}(u) - 1 \quad f_j := I_{j+1} - I_j \quad f_{\mathrm{last}(u)} := N - I_{\mathrm{last}(u)}$$

Define two utility functions "freq" and "index" below. These are then applied to the

$$\mathrm{freq}(n) := \overrightarrow{(n = u)} \cdot f \quad \mathrm{index}(n) := \overrightarrow{(n = u)} \cdot I$$

$$i := 0 .. N - 1$$

$$D_{i,2} := \mathrm{index}\left(D_{i,0}\right) + 1 + \left(\frac{\mathrm{freq}\left(D_{i,0}\right) - 1}{2}\right)$$

The first few rows of D now look like

Dpart := D

Dpart =

0.2	1	41.5
0.7	0	0.5
0.9	2	0.5
1.1	2	0.5
1.3	2	0.5
1.5	3	0.5
1.7	1	0.5
1.9	0	0.5
2.2	3	0.5
2.5	2	0.5
2.6	2	0.5
2.7	3	0.5
2.8	1	0.5
3.1	1	0.5
3.1	3	0.5

1. first colum is the TSS loading
2. second column is the number of the data set the values came from
3. the third column is the rank of the data value. Average ranks used for duplicate values

Now compute the sums of the ranks assigned to each of the K groups.

$$i := 0 .. k - 1$$

$R_i := \overrightarrow{\Sigma\left(D^{<1>} = i\right) \cdot D^{<2>}}$ **This statement separates the data by data set number, then sums the ranks of the data in each data set. Calls each value of R and puts it in a vector.**

$$R = \begin{bmatrix} 9 \\ 52 \\ 9.5 \\ 11.5 \end{bmatrix}$$

We are now ready to compute the value of K.

$$K := \frac{12}{N \cdot (N+1)} \cdot \sum_i \frac{\left(R_i\right)^2}{n_i} - 3 \cdot (N+1)$$

$$K := \frac{K}{1 - \frac{1}{N^3 - N} \cdot \overrightarrow{\Sigma f^3 - f}}$$

$K = -248.757$ **Kruskal Wallis statistic computed from the data**

The Test: If the size of the sample from each population is at least 5, then the statistic K, under the null hypothesis, will closely follow a chi-square distribution with degrees of freedom

$df = k - 1$ where k is the number of groups, 4 in this case

The acceptance criteria then will involve the chisq function. <u>Further, there is only a single, one-tailed test case:</u> If K is acceptably small, accept the null hypothesis.

At the level of significance α, ($\alpha := 0.05$) the acceptance criteria for the hypothesis that the k populations follow the same distribution is given by:

We have $k := 4$ groups, so $df := k - 1$ or $df = 3$. We have already determined the value of K for the data as $K = -248.757$. The critical chi square value is:

$$\mathrm{qchisq}(1 - \alpha, df) = 7.815 \quad .$$

Thus, we have to accept the null hypothesis that the loadings from all 4 sites have identical distributions. <u>However, note that the computed statistic is very close to the critical value.</u>

We accept the hypothesis that loadings from all sites have identical distributions

The picture below shows a χ^2 distribution having df = 3 degrees of freedom along with the test's critical value and the observed K. The critical value in this case was obtained using the root function. The value obtained is quite close to that obtained directly from the "qchisq" function above.

guess := 3

critical_K := root(pchisq(guess, df) − (1 − α), guess)

critical_K = 7.789 **[compare to 7.81 obtained above]**

x := 0, 0.1 .. 30 **plotting value**

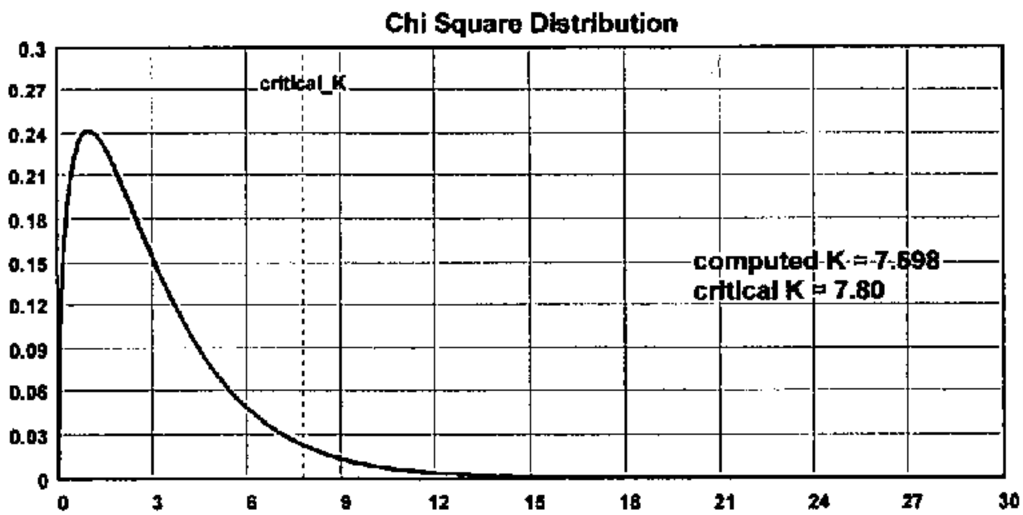


Figure I.1: Chi-Square Distribution

The Mann-Whitney U Test
A Procedural Example

Introduction

Earlier we described a parametric test for comparing the means of two populations using the Student's t distribution. The Mann-Whitney U test is, in some sense, a non-parametric alternative to the Student's t test.

Given samples from two populations, the Mann-Whitney U test is used to test the hypothesis

H_0: the two populations follow the *same* distribution

or

H_0: there is no significant difference between the populations

Below we read in two data sets. These are the TSS yields (lbs/acre/in) for sites 1 and 2 in West Monroe.

SITE1 :=

A:\TSS Load Pounds per Inch Rain per Acre site 1.txt

SITE2 :=

A:\TSS Load Pounds per Inch Rain per Acre site 2.txt

SITE3 :=

A:\TSS Load Pounds per Inch Rain per Acre site 3.txt

SITE4 :=

A:\TSS Load Pounds per Inch Rain per Acre site 4.txt rows(SITE1) = 18 mean(SITE1) = 23.306

rows(SITE2) = 22 mean(SITE2) = 39.477

The data in the vector SITE1 represents a sample of 18 loadings. Similarly the vector SITE2 contains similar data, 22 values. We'll use the Mann-Whitney U test to test the hypothesis that the two data sets are from the same population.

Conditions

Since this is a non-parametric test, we need no assumptions about underlying population distributions so there is really only one condition which must be satisfied to conduct a U test

i) you must have two samples randomly selected from each of two populations where you wish to determine, with some uncertainty, whether the populations are the same.

The Test Statistic

The Mann-Whitney U test works as follows

- first lump the two sets of data into a single group
- rank the pooled data
- compare the sums of the ranks from 1 population with that of the other. Under the assumption that the two populations are the same, the two rank sums should be close.

It is for this reason that the Mann-Whitney U test is also known as the *rank-sum* test.

Conducting the U test requires three computations:

- the Mann-Whitney statistic, denoted by U
- the theoretical mean of U assuming the hypothesis of identical distributions. We denote this mean by U_{mean}
- the theoretical standard deviation of U, assuming the hypothesis of identical distributions. We denote the standard deviation by s_U

We'll explain the computation of each, in turn.

Computing U **First determine sample sizes**

$n1 := \text{length}(SITE1)$ $n2 := \text{length}(SITE2)$

$n1 = 18$ $n2 = 22$

We need to pool the data for ranking but we don't want to lose track of which group what data came from, so we first attach a tag to each piece of data to remember its group.

$i := 0..n1 - 1$ $j := 0..n2 - 1$

$SITE1_{i,1} := 1$ $SITE2_{j,1} := 2$

SITE1 =

6.4	1
6.5	1
73.6	1
3.9	1
1.9	1
24.4	1
0.7	1
4.2	1
18.3	1
29.9	1
18.4	1
54.1	1
8.7	1
80.4	1
26.2	1

SITE2 =

12.8	2
6.6	2
120.5	2
2.8	2
10.6	2
0.2	2
79.3	2
95	2
176.4	2
3.1	2
25	2
6.6	2
132.2	2
10.6	2
36.4	2

Now pool the data into a single array by augmenting the matrices

$$D := \text{augment}\left(SITE1^T, SITE2^T\right)^T$$

sort on the first column for ranking purposes $D := \text{csort}(D, 0)$

A look at the first few entries in the two columns of D shows how our tagging has kept track of the data groups after pooling. The first column is the ranked data. The second column is the number of the data set it came from.

$$i := 0..8$$

$D_{i,0}$	$D_{i,1}$
0.2	2
0.7	1
1.7	2
1.9	1
2.8	2
3.1	2
3.4	2
3.9	1
4.2	1

We now need to assign ranks to each element, assigning the average rank to tied data. The rank will be stored in the third column of D. This is a several step process.

First we create a vector of the <u>distinct</u> values among the data

$$i := 1..n1 + n2 - 1 \qquad u_0 := \left(D^{<0>}\right)_0 \qquad z_0 := 1$$

$$u^{<0 \cdot 1>} := \text{if}\left[\left(D^{<0>}\right)_i = \left(D^{<0>}\right)_{i-1}, u, \text{augment}\left[u^T, \left(D^{<0>}\right)_i \cdot z\right]^T\right]$$

$u^T =$

0.2	0.7	1.7	1.9	2.8	3.1	3.4	3.9	4.2	6.4	6.5	6.6

and the indices of where they first appear in D

$$I_0 := 0$$

$$I^{\langle 0\cdot 1\rangle} := \text{if}\left[\left(D^{\langle 0\rangle}\right)_i = \left(D^{\langle 0\rangle}\right)_{i-1}, I, \text{augment}\left(I^T, i\cdot z\right)^T\right]$$

The frequencies of each value within the pooled sample can be found easily

$$k := 0 .. \text{last}(u) - 1$$

$$f_k := I_{k+1} - I_k$$

$$f_{\text{last}(u)} := n1 + n2 - I_{\text{last}(u)}$$

Look at the vectors u and f. The vector u shows the distinct values of the data while the vector f shows how many times that value occurs in the data set

$u^T =$

0.2	0.7	1.7	1.9	2.8	3.1	3.4	3.9	4.2	6.4	6.5	6.6

$f^T =$

1	1	1	1	1	1	1	1	1	1	1	2

We define two utility functions

$$\text{freq}(n) := \overrightarrow{n = u\cdot f} \qquad \text{index}(n) := \overrightarrow{n = u\cdot I}$$

and we're ready to assign ranks

$$i := 0 .. n1 + n2 - 1$$

$$D_{i,2} := \text{index}\left(D_{i,0}\right) + 1 + \left(\frac{\text{freq}\left(D_{i,0}\right) - 1}{2}\right)$$

Let's look at a portion of D

rows: $r := 0 .. 12$ columns $c := 0 .. 2$

$$\text{Dpart}_{r,c} := D_{r,c}$$

$$Dpart = $$

0.2	2	1
0.7	1	2
1.7	2	3
1.9	1	4
2.8	2	5
3.1	2	6
3.4	2	7
3.9	1	8
4.2	1	9
6.4	1	10
6.5	1	11
6.6	2	12.5
6.6	2	12.5

column 1 data value
column 2 data set value came from
column 3 rank of data value

Continuing our computation of the U statistic, we sum the ranks associated with group 1

$$S1 := \sum \overrightarrow{\left(D^{<1>} = 1\right) \cdot D^{<2>}} \qquad S1 = 354.5$$

$$S2 := \sum \overrightarrow{\left(D^{<1>} = 2\right) \cdot D^{<2>}} \qquad S2 = 465.5$$

and compute

$$U_1 := \left[n1 \cdot n2 + \frac{n1 \cdot (n1 + 1)}{2}\right] - S1 \qquad U_1 = 212.5$$

$$U_2 := n1 \cdot n2 + \frac{(n2 + 1) \cdot n2}{2} - S2 \qquad U_2 = 183.5$$

And that's the computation of the Mann-Whitney statistic U.

Computing U_{mean}

Necessary for conducting the rank-sum test is the mean of the U statistic which we denote by U_{mean}. This is an easy computation. The formula is expected value of U_{mean} $\quad U_{mean} := \frac{n1 \cdot n2}{2}$

the product of the sample sizes divided by 2.
For our data we have $U_{mean} = 198$

Computing s_U

The last piece needed for the rank-sum test is the standard deviation of U which we represent by s_U. This computation is a little more complicated than the mean.

We define N as the total number of data points

$$N := n1 + n2$$

Next we compute a quantity which accounts for the variance due to ties in the data. This uses the frequency vector computed earlier.

$$T := \sum \overrightarrow{\frac{f^3 - f}{12}}$$

Now we compute the standard deviation of the Mann Whitney Statistic: s_U. Use 2 different computation equations to be sure they compute the same thing.

$s_U := \sqrt{\frac{n1 \cdot n2}{N \cdot (N-1)} \cdot \left(\frac{N^3 - N}{12} - T \right)}$ results in $s_U = 36.778$ ref: Mathsoft

$s_{U2} := \sqrt{\frac{n1 \cdot n2 \cdot (n1 + n2 + 1)}{12}}$ results in $s_{U2} = 36.783$ reference: Mendenhall 7th Edition, Introduction to Probability and Statistics

These two equations provide essentially the same answer. Thus we are ready to describe the Mann-Whitney U test.

The Mann Whitney U test approximation for large samples, i.e. n1 and n2 > 10

It has been shown that the statistic U approximately follows a normal distribution as soon as the number of data points gets at all large, say

$n1 \geq 10 \qquad n2 \geq 10 \qquad n1 = 18 \qquad n2 = 22$

and so we use the normal distribution to carry out the test.

For reasons we'll give later, the U test is typically performed as a two-tailed test. The test criteria, then, at the α level of significance is

$$z_{\alpha} := \left| \frac{U_2 - \frac{n1 \cdot n2}{2}}{\sqrt{n1 \cdot n2 \cdot \frac{(n1 + n2 + 1)}{12}}} \right|$$

$z_{\alpha} = 0.394$ **The acceptance value for z_{α} is $\mathrm{qnorm}(.975, 0, 1) = 1.96$**

Thus, we accept the hypothesis that the TSS yields from SITE 1 and SITE 2 have identical distributions

Let's look at this graphically.

The graph below shows the theoretical distribution of U, the observed test statistic U.

$U := 200 \qquad \alpha := .05$

$$\mathrm{pnorm}\left(U_2, U_{mean}, s_U\right) = 0.3 \quad (1 - \alpha) = 0.95$$

$$c1 := \mathrm{root}\left[\mathrm{pnorm}\left(U, U_{mean}, s_U\right) - \left(1 - \frac{\alpha}{2}\right), U\right] \qquad c1 = 269.618$$

$U := 0, 10 .. 500 \qquad U_{mean} = 198 \qquad \frac{c1 - U_{mean}}{s_U} = 1.947$

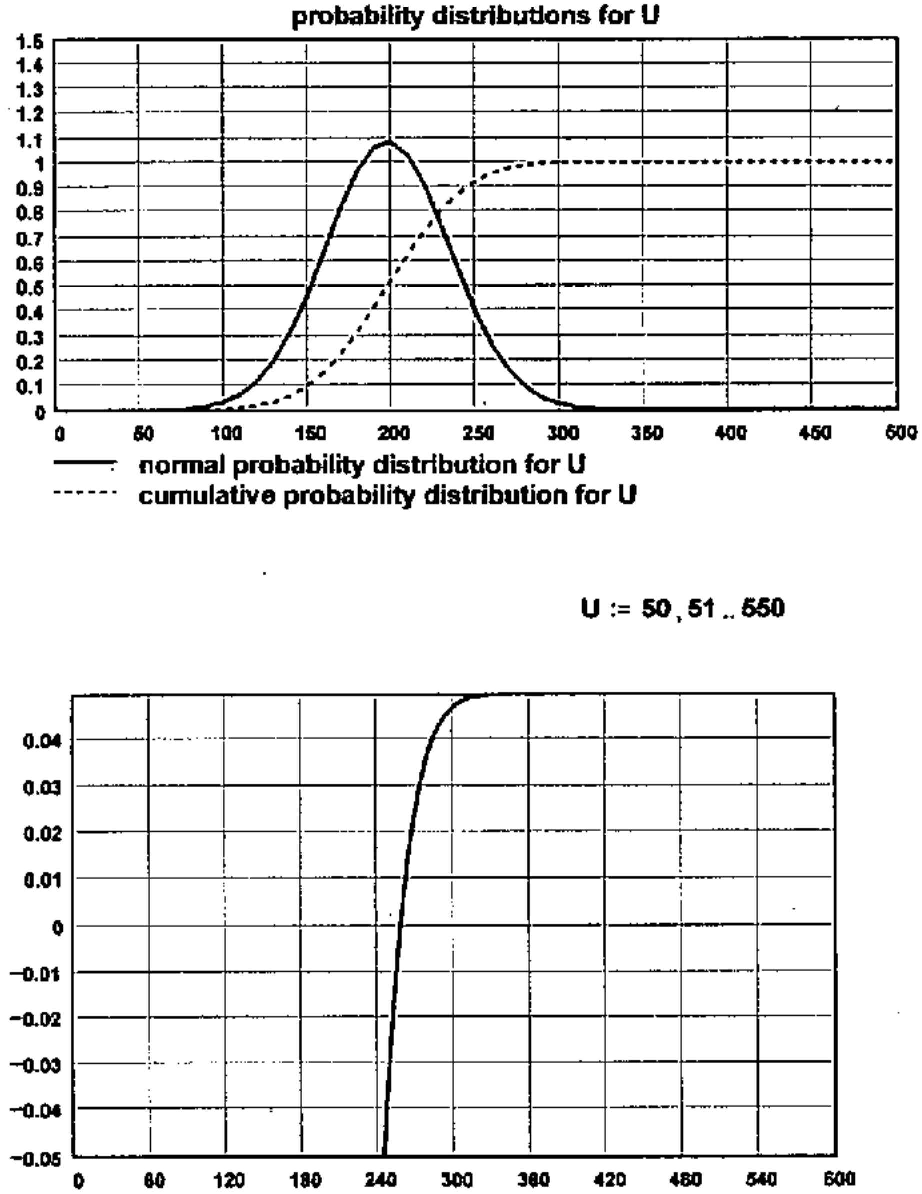


Figure I.2: Mann-Whitney Theoretical Distribution of U

Appendix J
Recorded Rainfall Events

Table J.1: Recorded Rainfall Events

Date	Time	Rainfall Amt.(inches)
2/19/98	8:45pm-9:25pm	0.14
2/20/98	7:50am-7:55am	0.57
2/22/98	6:20am-12:55pm	1.2
2/26/98	3:35am-10:45am	1.55
3/4/98	10:45am-11:01am	0.07
3/5/98	7:45pm-8:38pm	2.65
3/7/98	7:14am-6:53pm	2.95
	No flow data from 3-9-98 to 3-11-98	
3/16/98	2:39pm-6:46pm	2.39
3/31/98	7:51am-10:09am	0.15
4-2-98 to 4-3-98	7:08pm 4-2-98 - 12:48am 4-3-98	0.23
4/18/98	2:05am-5:30pm	2.03
4/27/98	1:20am-3:10am	0.11
4/27/98	6:45pm-11:10pm	4.47
5/3/98	12:25am-3:05am	0.98
5/29/98	2:10pm-2:40pm	0.27
6/5/98	2:10am-3:55am	0.19
6/5/98	10:35am-11:50am	0.46
6-5-98 to 6-6-98	6:20pm-2:00am	1.26
6/15/98	12:25am-12:40am	0.08
6/15/98	8:30pm-8:40pm	0.04
7/1/98	4:55pm-6:40pm	0.21
7/2/98	8:55am-10:15am	0.2
7/9/98	5:10pm-5:25pm	0.28
7/13/98	7:20am-10:05am	0.7
7/21/98	4:45pm-5:45pm	0.55
7/25/98	6:10pm-9:15pm	2.12
8/6/98	8:50pm-10:50pm	0.46
8/12/98	9:40am-4:40pm	1.47
8/13/98	1:25pm-2:50pm	0.65
8/14/98	6:00pm-6:40pm	0.33
9-11-98 to 9-12-98	2:25am-6:35pm	7.06
9/13/98	1:45pm-2:20pm	0.08
9/14/98	4:05am-9:30am	0.73
9/18/98	8:50pm-9:50pm	0.58
9/19/98	2:05pm-3:30pm	0.51
10/3/98	6:20am-12:35pm	0.28
10/6/98	11:00am-3:35pm	0.31
10/19/98	12:20am-2:50am	0.48
10/20/98	5:55am-9:40am	0.25
11/1/98	6:55pm-10:50pm	1.17

Table J.1 (continued): Recorded Rainfall Events

Date	Time	Rainfall Amt.(inches)
11-7-98 to 11-8-98	11:45am-8:20am	2.03
11/10/98	5:40am-6:50am	0.29
11-12-98 to 11-13-98	10:20am-6:40am	0.88
11-13-98 to 11-14-98	4:00pm-12:55pm	2.74
11/20/98	5:40am-7:25am	0.55
12/8/98	1:50am-5:45am	0.57
12-10-98 to 12-12-98	10:25am-6:05am	6.09
12-18-98 to 12-19-98	9:25pm-12;55am	0.96
12-21-98 to 12-22-98	9:20pm-2:10am	0.8
12/25/98	11:30am-1:35pm	0.19
12/26/98	10:10am-2:15pm	0.24
12-27-98 to 12-28-98	6:40pm-12:30am	0.77
1/1/99	11:30am-7:35pm	0.9
1/2/99	12:50am-6:15am	2.29
1-7-99 to 1-8-99	10:05pm-1:10am	0.19
1-9-99 to 1-10-99	3:25pm-2:50am	1.88
1/21/99	9:45pm-10:40pm	0.32
1/22/99	5:15am-1:15pm	3.56
1/22/99	12:10pm - 1:15pm	0.24
1/28/99	8:50am - 10:50am	0.33
1-28-99 to 1-30-99	3:50pm 1-28-99 to 6:25am 1-30-99	10.74
2/11/1999 to 2-12-99	9:25pm 2-11-99 to 12:30am 2-12-99	0.23
2/17/99	2:25am - 6:05am	0.26
2/20/99	5:30pm - 7:20pm	0.06
2/26/99	7:05pm - 7:10pm	0.08
2/27/99	2:15pm - 3:30pm	0.85
3/2/99	6:30pm - 8:05pm	0.63
3/8/99	5:35pm - 7:40pm	1.89
3/11/99	8:50am - 12:30pm	0.12
3/12/99	11:50am - 5:10pm	0.92
3/13/99	2:40am - 2:30pm	1.99
3/14/99	5:15am - 6:50am	0.07
3/20/99	2:10am -2:35am	0.04
3/24/99	4:25am - 5:40am	0.31
3/25/99	1:20am - 3:45 am	0.89
3/28/99	7:00pm -8:35pm	0.07
3/29/99 to3/30/1999	7:40pm 3-29-99 to 11:40pm 3-30-99	1.57
4/3/99 to 4/4/99	7:25pm- 2:10am	2.19

Table J.1 (continued): Recorded Rainfall Events

Date	Time	Rainfall Amt.(inches)
4-4-99 to 4-5-99	4:30pm - 12:00am	2.65
4/5/99	4:15pm - 10:25pm	0.06
4/15/99	3:35pm - 6:45 pm	2.33
4/26/99	2:20pm - 4:00pm	0.44
5/3/99	3:55am - 6:05 am	0.02
5/4/99	4:40pm - 5:00 pm	0.03
5-4-99 to 5-5-99	10:50pm - 12:45am	1.16
5/10/99	12:55pm - 3:40 pm	0.08
5/17/99	10:50pm - 11:55pm	0.33
5/30/99	1:05pm - 1:30pm	0.04
5-30-99 to 5-31-99	11:00pm - 12:55am	0.32
6/9/99	6:30pm - 6:35pm	0.04
6/10/99	4:50pm - 7:40 pm	0.18
6/11/99	6:25pm - 7:45 pm	0.03
6/12/99	6:00pm - 9:50 pm	1.95
6/14/99	8:15pm - 11:10pm	1.7
6/22/99	1:50pm - 5:05 pm	1.62
6/23/99	10:45 am - 3:20 pm	1.22
6/24/99	12:20 pm - 3:50 pm	0.12
6-24-99 tp 6-25-99	7:10 pm - 1:20 am	2.29
6/25/99	12:05 pm - 12:10 pm	0.03
6/25/99	3:50 pm - 8:10 pm	1.17
6/26/99	7:55 am - 10:05 am	0.04
6/26/99	5:20 pm - 11:30 pm	2.9
6/29/99	8:20 am - 8:45 am	0.29
7/3/99	7:05 pm - 7:10 pm	0.07
7/7/99	1:10 pm - 2:10 pm	1.44
7/9/99	12:35pm -2:35pm	0.51
7/11/99	2:50pm - 6:35pm	0.39
7/12/99	5:25am - 7:40am	0.12
7/13/99	9:10pm - 11:40pm	0.42
8/10/99	3:10pm - 4:25pm	0.23
8/24/99	1:00pm - 3:45pm	1.19
8/27/99	6:50am - 8:45am	0.74
8/31/99	7:00pm - 7:15pm	0.05
9/1/99	1:55pm - 3:35pm	0.98
9/2/99	3:35pm - 4:50pm	0.07
9/5/99	3:45pm - 4:05pm	0.79
9/5/99	7:05pm -11:10pm	0.07
9/6/99	11:50am - 1:40pm	0.07
9/8/99	8:20am - 11:30am	0.4
9/8/99	8:10pm - 9:00pm	0.18
9/28/99	2:50pm - 9:45pm	2.19
9/29/99	3:35am - 6:05am	0.22

Table J.1 (continued): Recorded Rainfall Events

Date	Time	Rainfall Amt.(inches)
10/7/99	3:05pm - 9:45pm	0.18
10/8/99	4:55pm - 8:10pm	0.84
10/8/99	11:00pm - 12:05am	0.02
10/19/99	2:45am - 6:55am	0.29
10/26/99	11:10am	0.03
10/31/99	12:00am - 3:05pm	0.18
10/31/99	4:20pm - 11:30pm	0.09
11/19/99	10:05pm 11-19 to 11:35am 11-20	0.4
11/23/99	12:25pm 11-23 to 12:20am 11-24	0.58
11/25/99	6:20am - 11:40am	0.18
12/3/99	1:45am - 9:45am	0.18
12/3/99	3:50pm 12-3 to 7:30am 12-4	0.54
12/4/99	7:40pm 12-4 to11:05am 12-5	1.42
12/9/99	3:55pm 12-9 to 2:40am 12-10	0.79
12/12/99	6:35am - 7:20am	0.05
12/12/99	1:05pm - 11:55pm	0.31
12/13/99	12:25am - 11:15pm	0.57
12/14/99	12:00am -11:25pm	0.57
12/15/99	12:10am - 12:10pm	0.14
12/18/99	2:30am - 6:25pm	0.94
12/20/99	4:45pm - 11:35pm	0.64
1/3/00	9:50am - 5:20pm	0.46
1/8/00	5:30am - 5:55pm	0.51
1/9/00	10:15pm 1-9 to 3:55 am 1-10	0.25

Appendix K
Site Comparison for
Pounds of Pollutants Discharged

Table K.1: COD Site Comparison Pounds and Basin Efficiency

Date	Site 1 Total lbs	Site 2 COD Total lbs	Site 3 COD Total lbs	Site 4 COD Total lbs	Basin Efficiency %
2/11/98	211		1,168		118.07
2/22/98		4,345		1,124	-286.57
2/23/98	40.68	1,864	127	820	-92.54
3/6/98	358	10,745	1,147	23,041	57.06
4/15/98		208		667	68.82
4/19/98	14	2,376	147	1,445	-48.37
6/5/98		88		51	-72.55
6/7/98		5,776	111	1,491	-260.55
8/10/98	1.84	704	22	56	-800.21
9/13/98	73	7216	317	3610	-81.89
9/14/98		523	93	157	-109.20
11/13/98	2.5	969		25	-3766.00
12/11/98	42	1,458	134	584	-97.21
1/9/99	74	9,079	385	2,136	-257.20
3/3/99	33	348	14	550	44.15
3/25/99	67	945	75	984	17.09
4/15/99	314	4,670	223	3,976	-3.74
5/5/99	35	1,316	44	1,751	28.64
6/14/99	380	682	123	813	67.74
6/23/99	156	2,142	272	3,886	52.24
7/8/99	51	1,584	43	2,946	48.71
9/29/99	221	857	85	1,494	59.72
12/6/99	40	900	31	940	11.43

Basin Efficiency Comparison - Overall Project and Yearly

	Site 1 Total lbs	Site 2 COD Total lbs	Site 3 COD Total lbs	Site 4 COD Total lbs	Basin Efficiency %
Totals Overall	**2114.02**	**58,795**	**4,561**	**52,547**	**0.75**
Total 1998	**743.02**	**36,272**	**3,266**	**33,071**	**2.22**
Total 1999	**1371**	**22,523**	**1295**	**19,476**	**-1.83**
Total After Dredging	**1297**	**13,444**	**910**	**17340**	**33.44**

* Basin Efficiency = ((Site 4+Site 3)-(Site 2-Site1)) x 100

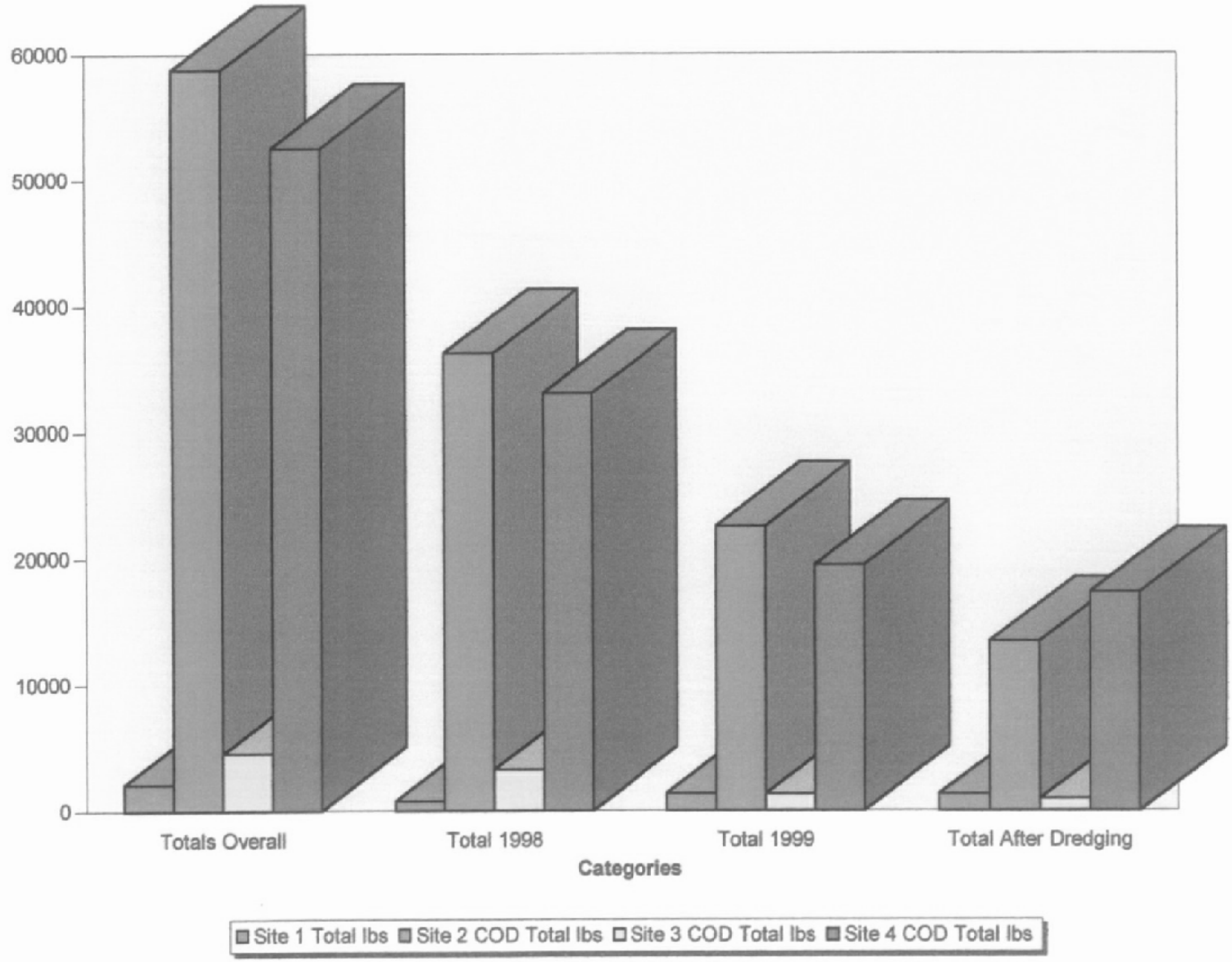


Figure K.1: Site Comparison Total Pounds COD

Table K.2: Total Phosphorus Site Comparison Pounds and Basin Efficiency

Date	Site 1 TP lbs	Site 2 TP lbs	Site 3 TP lbs	Site 4 TP lbs	Basin Efficiency % Per Rain Event
2/22/98	0	57.55	0	0	0
2/23/98	0.31	24	1.47	11	-89.98
3/6/98	4.71	235	12.4	210	-3.55
4/15/98	0	3	0	18	83.33
4/19/98	0.19	40	1.43	34	-12.36
6/5/98	0	0.54	0	0.86	37.21
6/7/98	0	134	1.13	5.4	-1952.07
8/10/98	0.044	52	0.35	3.76	-1164.14
9/13/98	1.23	136	5.8	56	-118.07
9/14/98	0	9	1.03	4.3	-68.86
11/13/98	0.01	11	0	0.53	-1973.58
12/11/98	0.49	50	1.24	29	-63.72
1/9/99	0.82	206	4.72	40.8	-350.75
3/3/99	0.45	11	0.12	11.5	8.21
3/25/99	0.39	26	0.45	18.7	-33.73
4/15/99	3.01	107	4.8	72	-35.40
5/5/99	0.24	36	0.55	45.5	22.35
6/14/99	3.55	12	1.21	11.5	33.52
6/23/99	1.64	23	3.8	90	77.23
7/8/99	0.58	57	0.9	83	32.75
9/29/99	3.76	20	0.94	57	71.97
12/6/99	0.715	19	0.23	17.5	-3.13

Basin Efficiency Comparison - Overall Project and Yearly

	Site 1 TP Total lbs	Site 2 TP Total lbs	Site 3 TP Total lbs	Site 4 TP Total lbs	Basin Efficiency Site Comparison
Totals Overall Project	22.139	1269.09	42.57	820.35	-44.50
Total 1998	6.984	752.09	24.86	372.85	-87.35
Total 1999	15.155	517	17.72	447.5	-7.87
Total After Dredging	14.335	311	13	406.7	29.31

* Basin Efficiency = ((Site 4 + Site 3)-(Site 2- Site 1) x 100

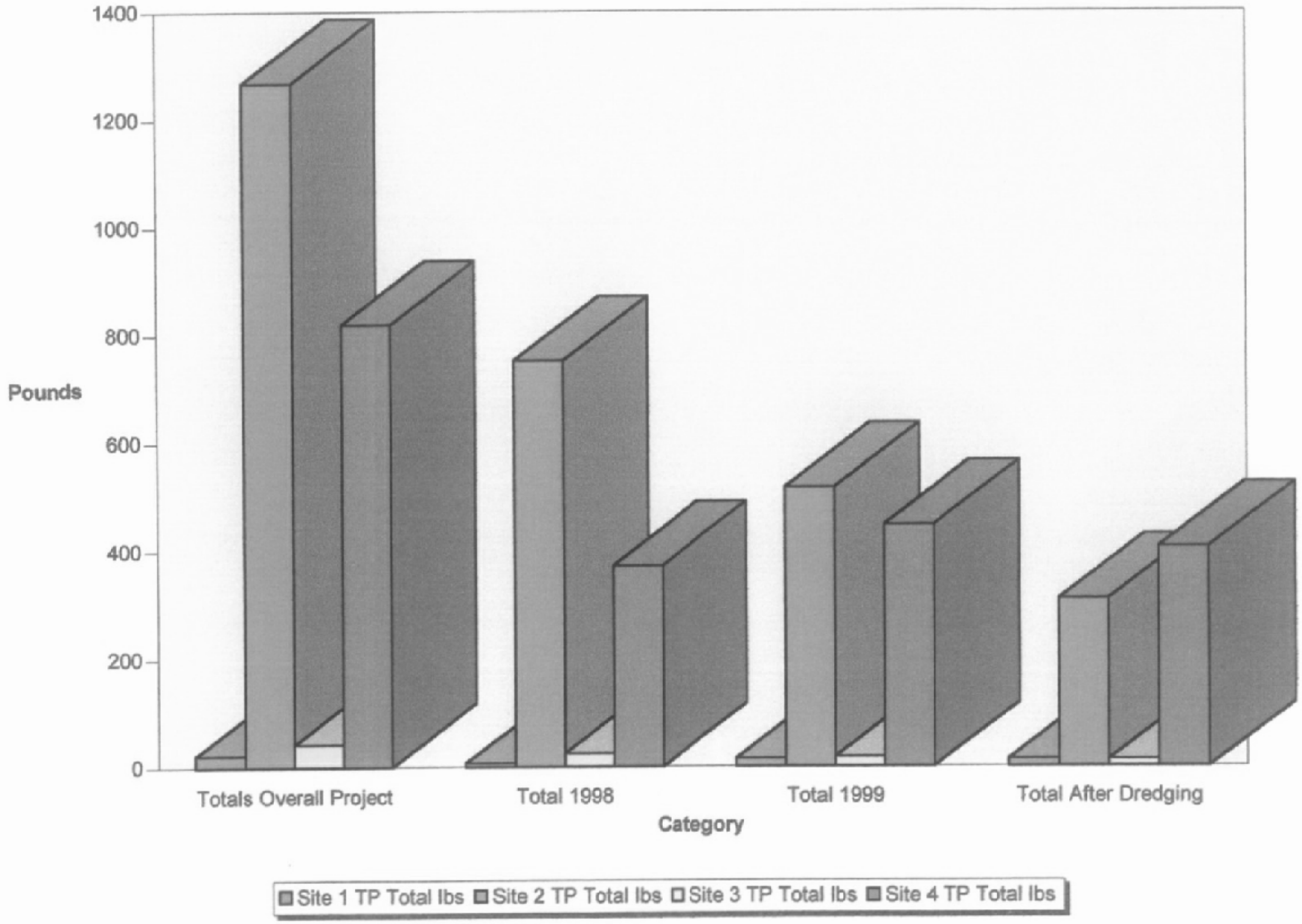


Figure K.2: Site Comparison Total Pounds Total Phosphorus

Table K.3: Total Suspended Solids Comparison Pounds and Basin Efficiency

Date	Site 1 TSS lbs	Site 2 TSS lbs	Site 3 TSS lbs	Site 4 TSS lbs	Basin Efficiency % Per Rain Event
2/11/98	240		7,919		103.03
2/22/98		13,586		6,244	-117.58
2/23/98	185	7,174	356	1,886	-211.73
3/6/98	14,893	291,248	18,634	211,301	-20.19
4/15/98		2,236		16,285	86.27
4/19/98	68	19,339	227	16,533	-14.98
6/5/98		70		535	86.92
6/7/98		99,870	324	33,254	-197.43
8/10/98	535	80,974	220	22,613	-252.29
9/13/98	1387	331,361	748	182,220	-80.35
9/14/98		2,231	86	7,882	71.28
11/13/98	64	12,890		1,094	-1072.39
12/11/98	815	28,576	179	10,524	-159.38
1/9/99	965	221,350	1446	64,394	-234.73
3/3/99	622	6400	29	12,298	53.13
3/25/99	1628	29,146	143	33,528	18.27
4/15/99	5274	142,514	1,700	165,018	17.68
5/5/99	1,130	31,005	358	66,812	55.52
6/14/99	7,448	8,110	620	5,009	70.47
6/23/99	3,987	43,945	1,564	143,476	72.45
7/6/99	623	35,444	432	106,350	67.39
9/29/99	4130	12,515	323	26,568	68.82
12/6/99	853	13,244	214	42,184	70.77

Basin Efficiency Comparison - Overall Project and Yearly

	TSS Site 1 Total lbs	TSS Site 2 Total lbs	TSS Site 3 Total lbs	TSS Site 4 Total lbs.	Basin Efficiency Site Comparison
Totals Overall	44847	1,434,228	35,622	1,175,808	-14.70
Total 1998	18187	889,555	28,693	510,171	-61.70
Total 1999	26660	544,673	6829	665,637	22.97
Total After Dredging	25695	323,323	5383	601243	50.94

* Basin Efficiency = ((Site 4 + Site 3)-(Site 2-Site 1) x 100

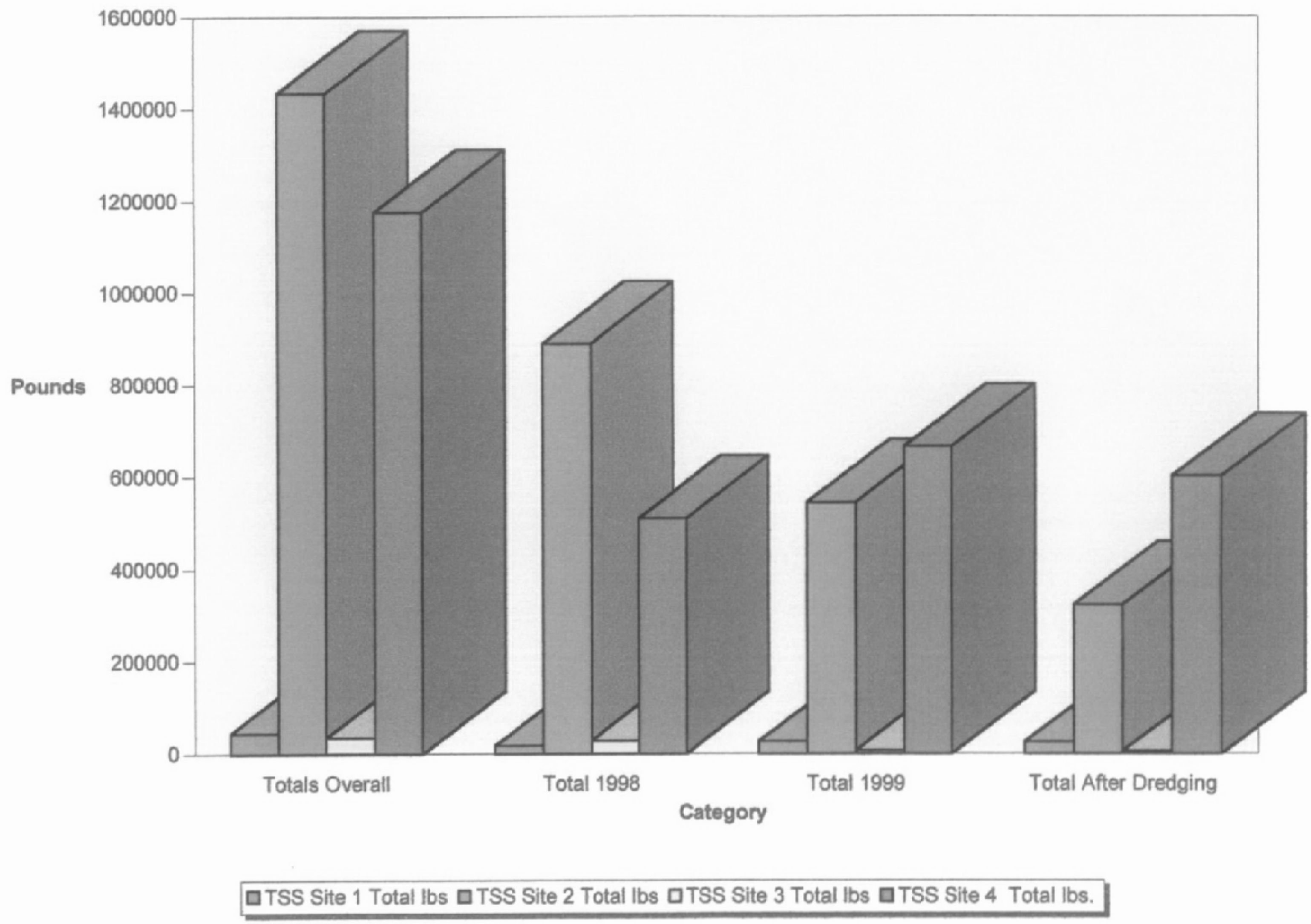


Figure K.3: Site Comparison Total Pounds TSS

Table K.4: NO_3 Site Comparison Pounds and Basin Efficiency

Date	Site 1 NO3 (lbs Load) Composite	Site 2 NO3 (lbs Load) Composite	Site 3 NO3 (lbs Load) Composite	Site 4 NO3 (lbs Load) Composite	Total Basin Efficiency %
2/22/98		419		68	0
2/23/98	5.67	192	10	144	-20.99
3/6/98	17	646	47	654	10.27
4/15/98		23		21.6	-6.48
4/19/98	2.22	248	12.4	120	-85.63
6/5/98		6.6		1.9	-247.37
6/7/98		285	7.5	45	-442.86
8/10/98	0.88	118.5	3.79	8.13	-888.74
9/13/98	2.6	248.6	8.78	84	-165.14
9/14/98		33.6	20	22	20.00
12/11/98	3.16	176	9.5	55.45	-166.11
1/9/99	4.46	790	1.26	180	-334.58
3/3/99	7.79	68	3.8	84.6	31.69
3/25/99	10.71	178.7	6.78	142.99	-12.17
4/15/99	63.27	1979	92.5	1,167	-52.10
5/5/99	60.8	1955	61.6	2,216	18.83
6/14/99	12.7	235	26	153	-24.19
6/23/99	7.23	342	99	649	55.24
7/8/99	10.9	491	19.5	785	38.80
8/29/99	11	67	2.78	149	63.10
12/6/99	0.4	10.5	0.19	9.7	-2.12

Basin Efficiency Comparison - Overall Project and Yearly

	Site 1 NO3 (lbs Load) Composite	Site 2 NO3 (lbs Load) Composite	Site 3 NO3 (lbs Load) Composite	Site 4 NO3 (lbs Load) Composite	Basin Efficiency Site Comparison
Total Overall	**220.79**	**8512.8**	**432.38**	**6,739**	**-15.61**
Total 1998	**31.53**	**2396.3**	**118.97**	**1,224**	**-76.13**
Total 1999	**189.26**	**6116.2**	**313.41**	**5,516**	**-1.68**
Total After Dredging	**184.8**	**5326.2**	**312.15**	**5336.29**	**6.98**

* Basin Efficiency = ((Site 4+Site 3) -(Site 2-Site 1)) x 100

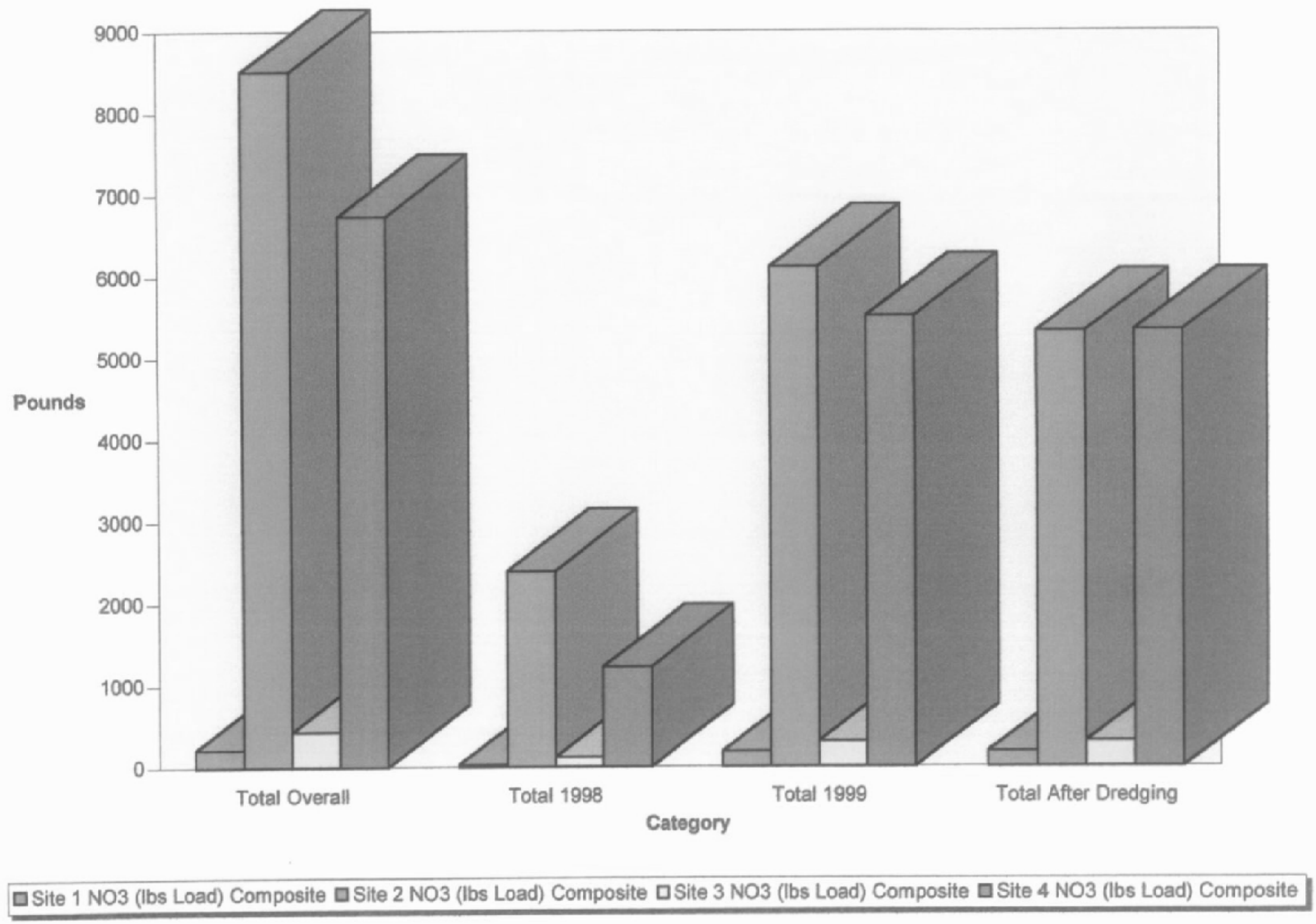


Figure K.4: Site Comparison Total Pounds NO_3

Table K.5: NH_3 Site Comparison Pounds and Basin Efficiency

Date	Site 1 NH3 (lbs Load) Composite	Site 2 NH3 (lbs Load) Composite	Site 3 NH3 (lbs Load) Composite	Site 4 NH3 (lbs Load) Composite	Total Basin Efficiency %
2/22/98		256		71	-260.56
2/23/98	1.28	120	6.6	26.5	-258.67
4/15/98		28		161	82.61
4/19/98	0.86	307	2.8	198	-52.46
6/5/98		0.99		5.95	83.36
6/7/98		118.5	0.65	13	-801.14
8/10/98	0.27	55.6	0.27	23.8	-129.87
9/13/98	0.86	126	5.69	44	-151.84
9/14/98		10.3	1.07	8.4	-8.76
11/13/98	0.08	18.9		0.71	-2550.70
12/11/98	0.606	16.9	1.17	8.87	-82.21
1/9/99	0.28	50	0.75	12	-293.04
3/3/99	0.28	3.8	0.11	6.1	43.32
3/25/99	2.12	28.44	2.51	18.4	-25.87
4/15/99	8.3	146	5.67	81	-61.37
5/5/99	0.25	12.8	0.31	31	59.92
6/14/99	1.61	4.66	0.59	23.4	87.29
6/23/99	1.04	38	3.5	43	20.52
7/8/99	2.58	21	0.93	41	56.07
9/29/99	0.24	0.51	0.72	4	94.23
12/6/99	0.01	3	0.12	2.5	-14.12

Basin Efficiency Comparison - Overall Project and Yearly

	Site 1 NH3 (lbs Load) Composite	Site 2 NH3 (lbs Load) Composite	Site 3 NH3 (lbs Load) Composite	Site 4 NH3 (lbs Load) Composite	Basin Efficiency Site Comparison
Total Overall	**18.666**	**1368.4**	**33.46**	**823**	**-67.61**
Total 1998	**3.956**	**1060.19**	**18.25**	**561**	**-82.43**
Total 1999	**14.71**	**308.21**	**15.21**	**262**	**-6.82**
Total After Dredging	**14.43**	**258.21**	**14.46**	**250.26**	**7.91**

* Basin Efficiency = ((Site 4 + Site 3) - (Site 2 - Site 1)) x 100

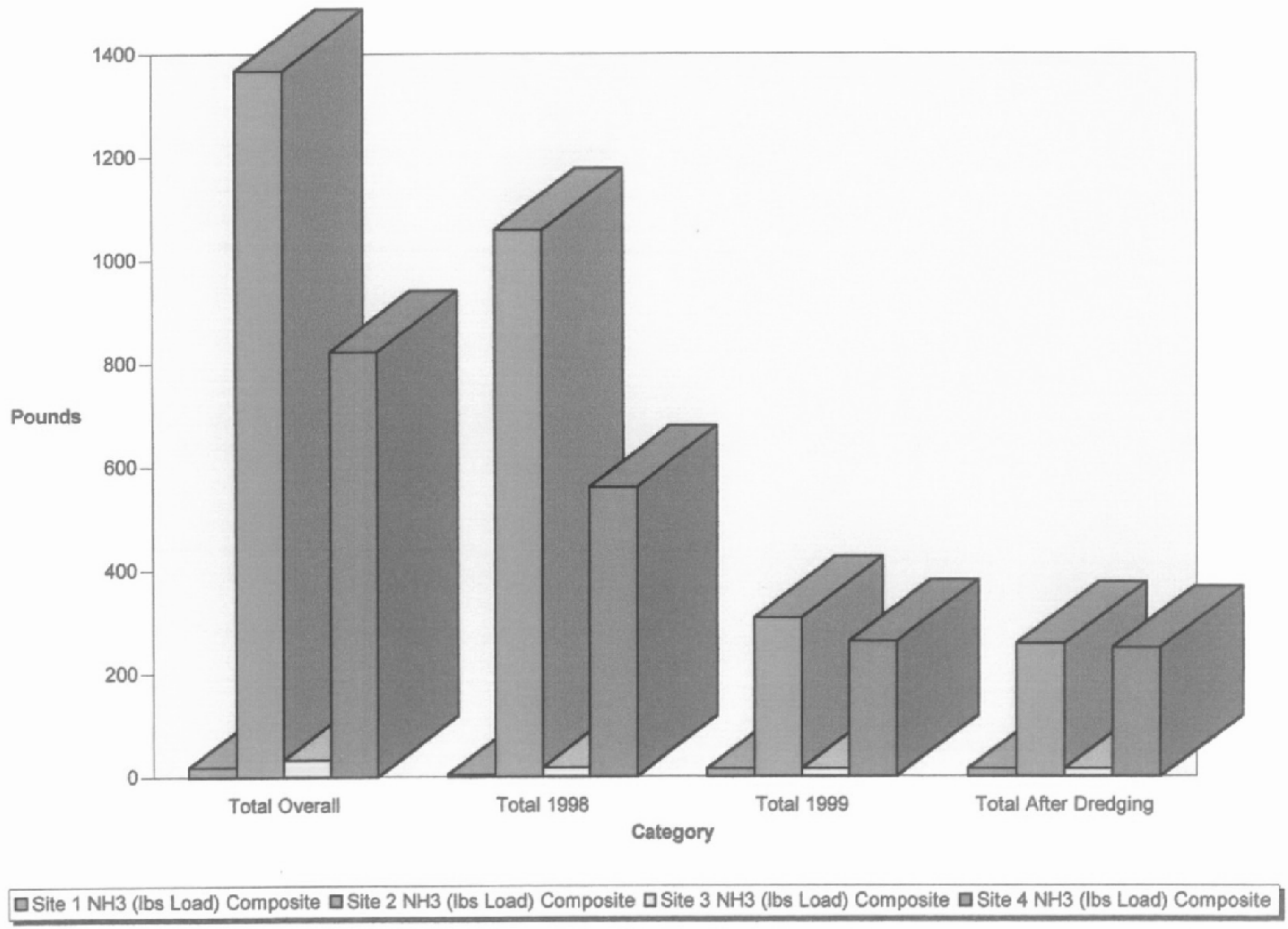


Figure K.5: Site Comparison Total Pounds NH_3

Table K.6: BOD Site Comparison Pounds

Date	Site 1	Site 2	Site 3	Site 4	Basin Efficiency %
2/22/98	0.00	509.20	0.00	145.66	-249.58
2/23/98	0.29	144.50	8.91	91.00	-44.35
6/7/98	0.00	1517.52	0.00	56.65	-2578.64
9/12/98	4.57	19.84	6.21	432.16	96.52
12/11/98	2.07	190.66	9.57	65.23	-152.13
3/25/99	2.93	124.47	5.98	73.25	-53.40
6/14/99	31.37	94.06	11.64	7.08	-234.87
Total lbs	**41.23**	**2600.24**	**42.30**	**871.02**	**-180.19**

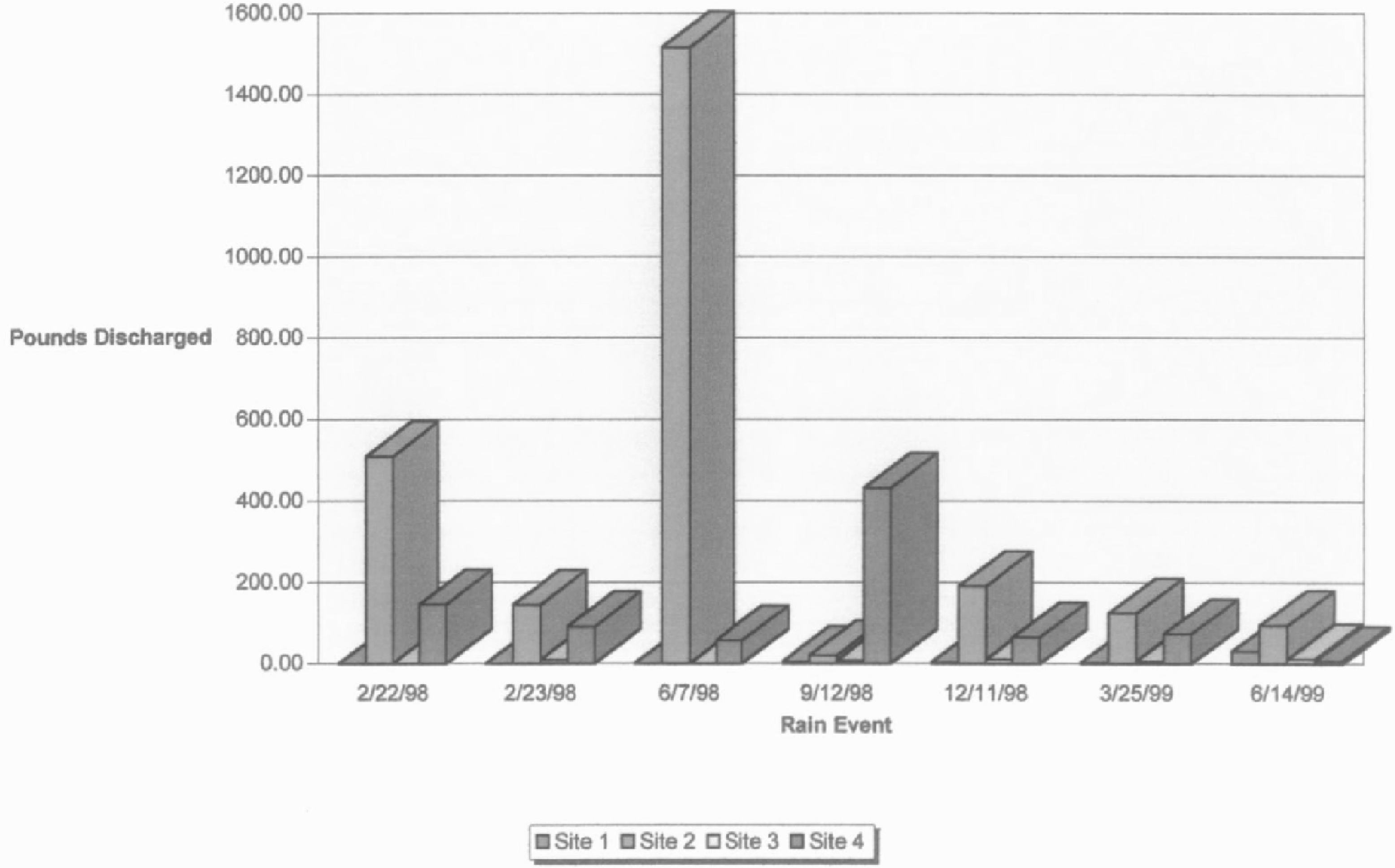


Figure K.6: Site Comparison Total Pounds BOD

Table K.7: TKN Site Comparison Pounds Discharged

Date	lbs TKN	lbs TKN	lbs TKN	lbs TKN	Basin Efficiency
	Site 1	**Site 2**	**Site 3**	**Site 4**	**%**
2/22/98		152.989		48.455	-215.73
2/23/98	0.108	55.705	9.328	34.805	-25.98
3/25/99	4.280	122.025	7.575	86.201	-25.56
6/14/99	8.159	54.707	4.046	37.681	-11.55
Total lbs	**12.547**	**385.426**	**20.949**	**207.143**	**-63.48**

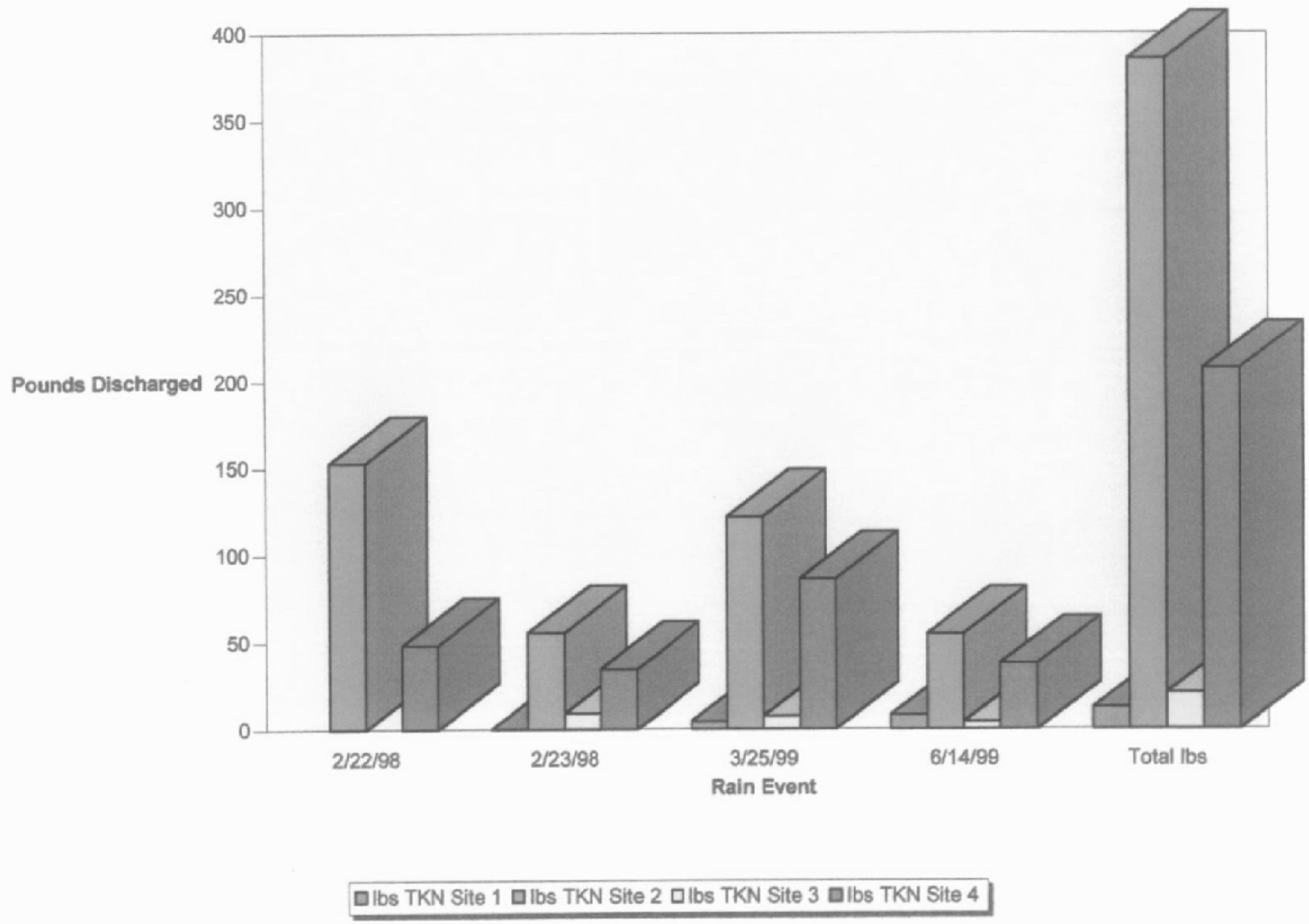


Figure K.7: Site Comparison Total Pounds TKN

Table K.8: Site Comparison TOC (mg/l)

Date	Site 1 (Commercial)	Site 2 (Wetland)	Site 3 (Residential)	Site 4 (Construction)	% Reduction
1/22/98	0	12	0	11	-9.09
2/15/98	11	0	7.9	0	0.00
6/5/98	16	10	18	15	69.70
3/30/99	15.8	9.7	22.4	9.7	69.78
6/23/99	8.2	23.3	39.7	22.3	62.42
				Average	**48.20**

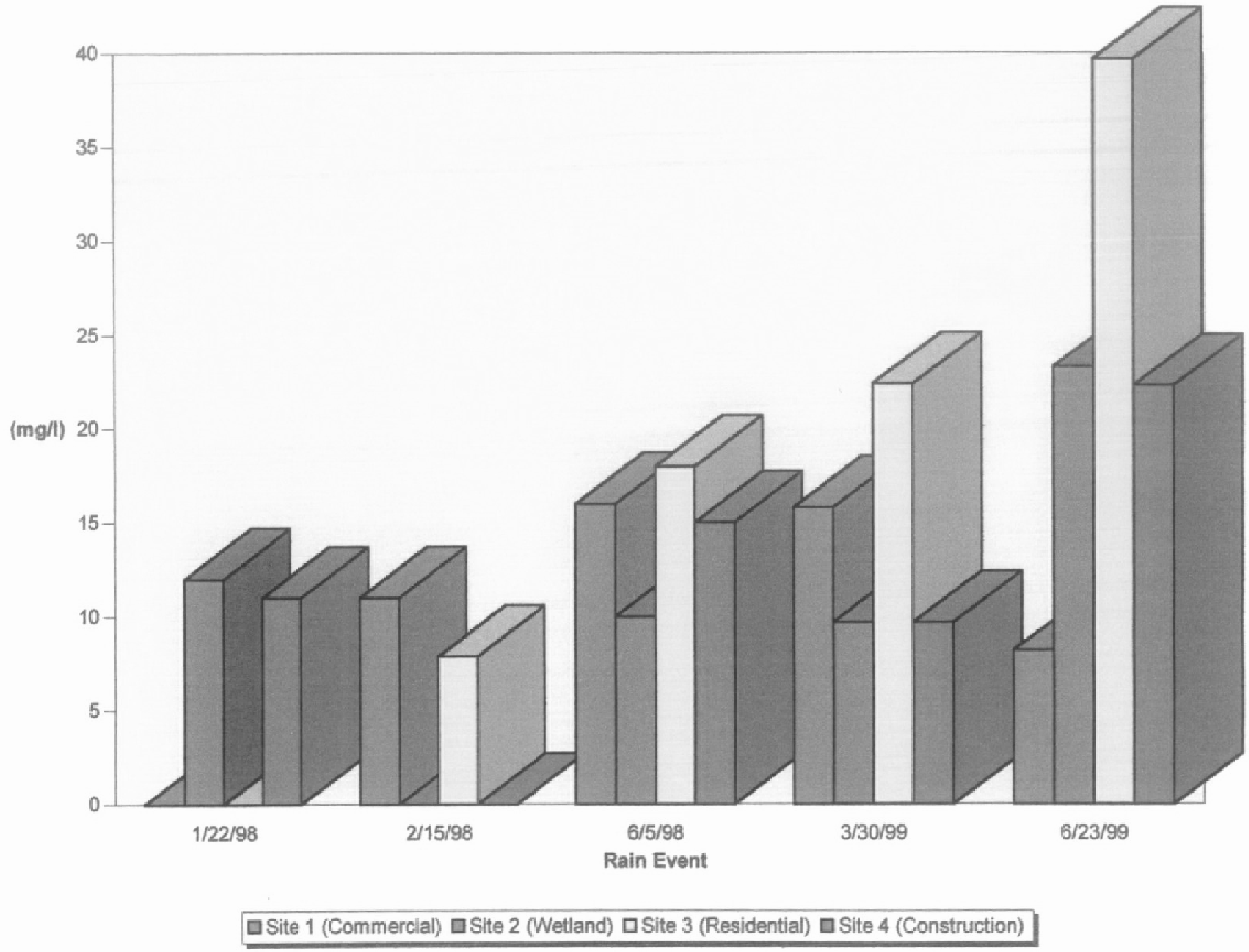


Figure K.8: Site Comparison TOC (mg/l)